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Corrosion Protection Selection Guide for Rapid Deployment Joint Task Force Facilities

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Corrosion Mitigation and Materials Selection Guide for Military Construction in a Severely Corrosive Environment

by
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The U.S. Army Corps of Engineers (USACE) guidance for military construction in the Middle East, called Standard Overseas Guide Specifications (SOGS), are reviewed to insure they incorporate the most effective corrosion mitigation techniques. The Middle East environment presents a unique set of corrosivity problems due to the desert sand, high winds, and warm, salt-laden atmosphere. These conditions, along with operation and maintenance constraints, can lead to costly premature corrosion failures.

Recommendations are given for optimizing protection against corrosion in this environment. This guidance can be incorporated into the SOGS where information is incomplete, outdated, or lacking; it can also be considered for revising the applicable Corps of Engineers Guide Specifications (CEGS).

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FOREWORD

This work was performed for the Directorate of Engineering and Construction, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162731AT41, "Military Facilities Engineering Technology"; Task Area A, "Facilities Planning and Design"; Work Unit 070, "Corrosion Protection Selection Guide for Rapid Deployment Joint Task Force Facilities." The HQUSACE Technical Monitor was Leslie Horvath, CEEC-EE.

This work was completed by the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. R. Quattrone is Chief, USA-CERL-EM. The USA-CERL technical editor was Dana Finney, Information Management Office. Dr. James R. Myers is with JRM Associates, Franklin, OH.

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COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

U.S. Army Corps of Engineers (USACE) military construction in the Middle East is a multimillion dollar, multiyear program for constructing and upgrading facilities for contingency use. The USACE Middle East Division has developed construction guidelines, called Standard Overseas Guide Specifications (SOGS), especially for Middle East projects. These SOGS were developed by modifying USACE's Guide Specifications (CEGS) to make them applicable to construction in the Middle East. The Middle East Division now uses these SOGS for most construction projects.

The Middle East environment in which these facilities are being constructed or upgraded (Saudi Arabia, Oman, Egypt, Kuwait, and Bahrain) is quite different from conditions typical in the United States. The desert sand, high winds, and warm, salt-laden air create an environment corrosive to even the most durable materials and coatings. The corrosivity of the environment, coupled with unique operation and maintenance (O&M) problems, can cause costly premature corrosion failures. Therefore, to insure that the SOGS covering corrosion protection incorporate all of the most recent methods available, the U.S. Army Construction Engineering Research Laboratory (USA-CERL) was asked to review these SOGS and recommend any changes or additions that would maximize facility lifetime through corrosion mitigation.

Objective

The objective of this work is to develop a corrosion mitigation and materials selection guide for all phases of the design and construction cycle in a severely corrosive environment such as that found in the Middle East (e.g., engineering design and review, onsite construction inspection, and analysis of contractor-submitted alternative materials).

Approach

The data necessary to develop corrosion protection information for facilities being constructed in the Middle East were obtained from three sources. First, the lessons learned from the performance of materials and protective coatings specified for previous USACE construction in the Middle East were reviewed. Second, the performance of materials exposed to similar environments, both in the laboratory and field, was documented. Third, state-of-the-art materials were surveyed to determine which materials are optimal for corrosion resistance in Middle East facilities construction.

Scope

This report focuses on materials and protective coatings for corrosion mitigation of facilities being constructed in a highly corrosive environment such as that found in the Middle East. The information can apply to construction in most similar environments.

Mode of Technology Transfer

It is recommended that the information in this report be incorporated into the appropriate SOGS and CEGS where current guidance is lacking, incomplete, or outdated. Appendix A is a cross reference between CEGS and SOGS.

2 ENVIRONMENT AND GENERAL REQUIREMENTS FOR CORROSION PROTECTION

Several environmental factors must be considered before selecting materials for military construction in the Middle East: (1) soil resistivity, (2) temperature, (3) relative humidity and rainfall, and (4) wind. In addition, the environmental conditions depend on the geography--specifically, coastal versus inland location. Coastal data were obtained from Masirah Island, Oman, and Ras Banas, Egypt; inland data were obtained from Thumarit, Oman. Average conditions can be summarized for each location.

Coastal Regions

In coastal areas, a combination of elements form a highly corrosive, severe desert environment.

Soil Resistivity

Using the soil box test method, some wet soil resistivities as low as 40 ohm-cm* were read. The average resistivity ranged from 30 to 1500 ohm-cm for Masirah Island and less than 1000 ohm-cm for Ras Banas. This severely corrosive environment is primarily a result of the high chloride and sulfate content in the soil. Note: an area's corrosivity can be rated from "severely corrosive" to "not likely corrosive" based on soil resistivity as shown below:

Soil resistivity range (ohm-cm)	Corrosivity rating
0 - 2000	Severe
2000 - 10000	Severe to moderate
10000 - 30000	Mild
30000 and above	Not likely

Temperature

The yearly mean temperatures are 78.8°F for Masirah Island and 78.4°F for Ras Banas. During summer, the temperatures are much more extreme, with highs above 100°F for a 4-month period.

Relative Humidity and Rainfall

The relative humidity is typically high. Masirah Island has an annual mean relative humidity of about 70 percent and less than 1 in. annual rainfall. Ras Banas has an annual mean relative humidity of about 43 percent and 4.4 in. annual rainfall.

Winds

The average coastal wind velocity is relatively high. Masirah Island has an average wind velocity of 21.9 mph; the average at Ras Banas is 16.1 mph. At some locations, such as Masirah Island, gale winds between 25 and 60 mph may occur at least once a month.

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*Metric conversions are provided on p 121.

Inland Regions

Inland conditions are also severe and extreme. Corrosion problems clearly are of major concern in this harsh environment.

Soil Resistivity

Wet box soil resistivities ranged from 60 to 220 ohm-cm, which is severely corrosive.

Temperature

The yearly mean temperature is approximately 80°F with the actual temperature exceeding 100°F during summer.

Relative Humidity and Rainfall

The relative humidity can vary from very low to relatively high, depending on the time of year, the proximity of the ocean, and the direction of prevailing winds. The total annual rainfall is generally less than 1 in.

Winds

The mean monthly winds are of moderate intensity. There are often days with blowing dust and sand.

Regional Requirements for Corrosion Mitigation

Some general requirements can be identified for protection against corrosion in the unique Middle East environment. Each of the following recommendations is discussed in greater detail for specific items and materials; the information is summarized here to provide a perspective for the rest of the report.

Underground Piping

Protecting underground pipes is a major concern because of the extremely corrosive soils in most parts of the Middle East. Ideally, all ferrous piping, including polyethelene bonded pipe, shall be cathodically protected. Polyethylene encasement (loose sleeving) is considered acceptable only for ductile cast-iron piping and not for other buried pipe materials.

Exterior Galvanized Steel

All exterior galvanized steel exposed to coastal or polluted industrial environments must be coated. If left unprotected, the galvanizing will be consumed rapidly. Due to synergistic effects, the protection afforded by a combined coated and galvanized system is greater than the sum of the protection afforded from each individual coating system. The one drawback with this system is that not all coatings are compatible with galvanizing. Therefore, a suitable coating system must be selected as detailed in **SOGS Section 09900.**

Weathering (CORTEN) Steel

CORTEN steel should not be specified for facility construction in most Middle East locations. This steel forms a protective oxide layer only when subjected to environmental air pollutants (particularly sulfides) combined with wet and dry cycles. Without these conditions, CORTEN steel corrodes at the same rate as mild steel.

Dissimilar Metal

Dissimilar metal contact should be avoided when possible. If contact cannot be avoided, the dissimilar metals should be isolated electrically using proper gaskets or coatings.

Metallic Fasteners

When possible, use metallic fasteners of the same or slightly more noble (e.g., stainless steel) material as the parts being fastened.

Grounding Rods and Grids

All copper grounding grids should be cathodically protected when the copper-to-earth potential is more positive than -0.25 V for most soils. The potential should be checked routinely on all grounding grids and rods in addition to verifying proper grounding resistance.

Plastic (Polymer) Materials

For corrosive environments, polymeric materials can be advantageous since they do not corrode as do metals. However, certain polymers can be rapidly degraded with continuous exposure to high-intensity ultraviolet (UV) radiation from the sun. Exterior exposed polymer materials must be either inherently resistant to this degradation or protected by coatings, pigmentation, or UV-absorbing additives. Fiberglass-reinforced plastic ladders, floor gratings, walkways, manhole covers, doors, and similar items should be used whenever possible in highly corrosive coastal regions and for interior, high-salt-level exposures. Fiberglass items may have a higher initial cost but should prove more cost-effective in the long run due to lower maintenance needs.

Coatings

Protective coatings can be used for successful corrosion control. The coating system must be selected carefully based on environmental exposure and type of material to be protected. Proper surface preparation is essential for lasting performance. The degree of surface preparation depends on the type of coating sytem used and the exposure to which the system will be subjected. Severe exposures and critical applications usually demand high-performance coating systems and high degree of surface preparation.

Underground Storage Tanks

The exterior surfaces of underground steel storage tanks must be coated and cathodically protected. As discussed in **SOGS Section No. 15605,** it is mandatory for any new construction that all underground petroleum oil liquid (POL) storage tanks, whether steel or fiberglass, be of double-wall construction and equipped with a leak detection system.

3 HOW TO USE THIS SELECTION GUIDE

The techniques recommended in this report are for mitigating corrosion to real property and real property installed equipment in a severely corrosive environement. The topics covered include: (1) proper materials selection, (2) improved design, (3) application of metallic and nonmetallic coatings, (4) alteration of the environment, (5) use of inhibitors, and (6) use of cathodic protection. In many cases, two of these corrosion-mitigation techniques are discussed concurrently to illustrate the resulting synergistic effects.

The information is presented under the SOGS sections as listed by the USACE's Middle East Division. Four topics that may be of interest for Middle East construction but for which no SOGS exist are included in Chapter 14.

Only after a meaningful site survey has been conducted can this report be used properly. Data on the soil, water, and atmosphere at the construction/installation site must be gathered before the best materials and corrosion mitigation techniques can be selected cost-effectively.

Most sections in this guide present a materials selection table first. Most tables have three headings:

Component	*Environment - Exposure*	*Materials Selection*
A specific component for the item or items by the SOGS listed. In some cases, the section title describes the component well enough, with no description needed; in these cases, the component heading may be eliminated.	The exposure to specific environment applicable to the recommended materials selection are given.	The material(s) and/or procedure(s) needed for satisfactory corrosion control are listed. Some components may have several acceptable material choices. In these instances, the materials or procedures which are preferred are underlined; those not underlined are considered minimally acceptable. In all cases, life-cycle cost should be considered before a material is chosen.

Supplemental information may follow the materials selection table.

When specific materials and corrosion-mitigation recommendations are not given in this report, current practices followed by USACE are considered satisfactory.

4 SITEWORK

SOGS Section No. 02315: Steel H-Piles

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric/splash zone/ immersion	ASTM A 690-81a steels.[1]
Coastal - Atmospheric	ASTM A 588-82 steel.[2]

Corrosion Mitigation

Regardless of the steel used in fabrication, H-piles should be coated. Coatings (including surface preparation, coating application, and coating formulations) recommended for sheet piling in **SOGS Section No. 02411** are equally applicable for H-piles. H-piles can be jacketed with concrete for corrosion mitigation in the splash zone.[3] The jackets should extend from at least 3 ft above the mean high-water (MHW) line to at least 3 ft below the mean low-water (MLW) line. For severe conditions or where significant wave action is anticipated, the jackets should completely cover the H-piles from at least 3 ft below the MLW to the underside of the deck or bent. (Wave action is a function of the average height of the waves as they break. Assuming that light wave action is approximated by 2-ft waves, it is possible to define "significant" wave action as waves 4 ft high and larger.) The concrete formulation and thickness requirements are described in **SOGS Section No. 02411.** Alternatively, H-piles can be jacketed using an epoxy polyamide mastic (see **SOGS Section No. 02411).**

Since all practical coatings contain holidays,* H-piles should have cathodic protection when they will be used in submerged and mud/soil zones.[4] Cathodic protection will also be partially effective in the tidal zone (i.e., when the tide is in). Unless the structure is small or a large structure is extremely well coated, impressed current cathodic protection is usually more cost-effective than installing sacrificial zinc or aluminum-alloy anodes.

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[1] ASTM A 690-81a, "Specification for High-Strength, Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environments," *American Society for Testing and Materials (ASTM) Standards* (1983).

[2] ASTM A 588-82, "Specification for High-Strength, Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. Thick," *ASTM Standards* (1983).

[3] H. S. Preiser, "Jacketing and Coating," *Handbook of Corrosion Protection for Steel Pile Structures in Marine Environments* (American Iron and Steel Institute, Washington, D.C., 1981), pp 53-66.

*Voids on the surface left uncoated by accident or caused by damage.

[4] A. W. Peabody and W. F. Cundaker, "Technical and Practical Approaches to the Design of Corrosion Control Methods," *Handbook of Corrosion Protection for Steel Pile Structures in Marine Environments* (American Iron and Steel Institute, Washington, D.C., 1981), pp 121-164.

For H-pile rehabilitation, coatings or barrier systems (e.g., surrounding a corroded H-pile section with 0.060-in.-thick rigid polyvinyl chloride [PVC] and filling the volume between the PVC and the H-pile with mastic) should be applied or installed.[5]

SOGS Section No. 02317: Cast-in-Place Concrete Piles

Component	*Environment - Exposure*	*Materials Selection*
Steel casing	Coastal - Atmospheric/ splash zone/immersion	ASTM A 252-82 steel.[6]
Metallic jackets-- steel casing	Coastal - Atmospheric/ splash zone/immersion	Monel 400.

Corrosion Mitigation

When desired, exterior surfaces of the steel casings can be protected in the atmospheric, tidal, splash, submerged, and mud/soil zones using the coatings, jackets, and cathodic protection described in **SOGS Section Nos. 02411** and **02315** of this report. For steel cylinders, however, metallic jackets are generally preferred because they are more cost-effective for splash-zone protection than those made of concrete.

Metallic jackets (leg wraps) can be attached to the casings easily using preformed Monel 400, copper alloy no. 70600, or copper alloy no. 71500 sheathing.[7] Since there are several ways to jacket steel casing, Figure 1 should be considered for specific applications. The two half-cylinders of sheathing are placed around the casings in the splash zone and welded together. The sheathing is, in turn, secured to the casing by welding. In general, it is advisable to seal the capillary between the metal jacket and the casing with a coal-tar mastic to mitigate galvanic corrosion. However, this procedure is not mandatory according to the results of field tests conducted by Creamer.[8] When noble-alloy jackets are applied to steel casings, it is desirable to apply a heavy-duty coating (e.g., coal-tar epoxy) to the steel extending at least 3 ft beyond the ends of the jackets as described in **SOGS Section No. 02411.**

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[5]H.S. Preiser, "Jacketing and Coating," *Handbook of Corrosion Protection for Steel Pile Structures in Marine Environments* (American Iron and Steel Institute, Washington, D.C.), pp 165-188.
[6]ASTM A 252-82, "Specification for Welded and Seamless Steel Pipe Piles," *ASTM Standards* (1983).
[7]H. S. Preiser.
[8]E. V. Creamer, "Splash Zone Protection of Marine Structures," Paper No. OTC-1274, presented at the Offshore Technology Conference, Houston, TX (1970).

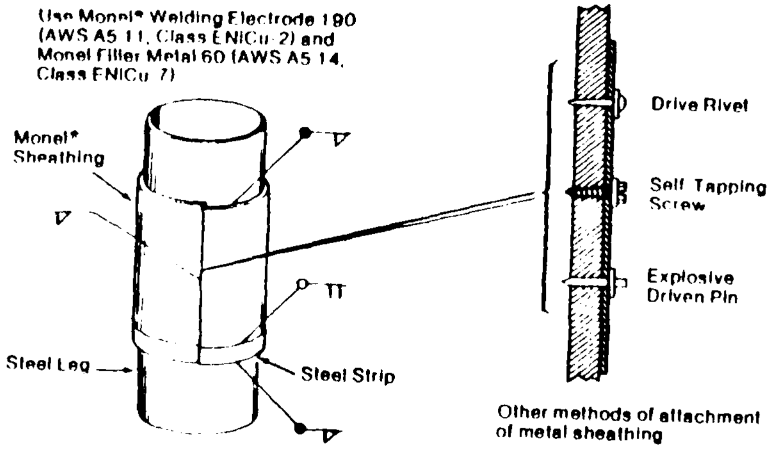

Figure 1. Field installation of Monel® sheathing. (From H. S. Preiser, "Steel Selection," *Handbook of Corrosion Protection for Steel Pile Structures in Marine Environments* [American Iron and Steel Institute, Washington, D.C., 1981], p 57. Used with permission.)

SOGS Section No. 02411: Steel Sheet Piling

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric/splash zone/immersion/soil	ASTM A 690-81a steel.[9] See comments below on cathodic protection, jacketing, and protective coatings.

Cathodic Protection

Sheet piling in contact with soil, mud, and saline waters should have cathodic protection using impressed-current systems with deep anode beds installed on the piling's shore side. The advantage of using deep anode beds is that both the water and soil sides of the piling can be protected by installing one system.

Since no cathodic protection method can protect the sheet pilings in the splash, tidal, and atmospheric zones, two options are available for corrosion control in these areas: (1) concrete jackets and (2) protective coatings.[10]

Jacketing. When concrete jackets are used, they should extend at least 3 ft below the MLW line. The minimum cover over the steel should be 4 in. Durability of the jackets can be increased by using: cements with 8 weight percent or less tricalcium aluminate, aggregates that are not reactive with the cement, rich mixtures such as 1:1:3

[9]S. K. Coburn, "Behavior of Steels in Marine Environments," *Handbook of Corrosion Protection for Steel Pile Structure in Marine Environments* (American Iron and Steel Institute, Washington, D.C., 1981), pp 196-197.
[10]H. S. Preiser.

or 1:1:2 for high-quality, maximum-density concrete, low water-to-cement ratios (e.g., 0.35 to 0.40), air entrainment to obtain 10 to 12 percent air voids, and low-chloride content water and aggregate (combined chloride content is 50 to 100 ppm). Concrete jackets can also be used to rehabilitate deteriorated sheet piling. However, concrete jackets must not be subjected routinely to impact by vessels or barges, since this would be expected to crack the concrete.

An epoxy polyamide mastic is also useful for jacketing. This material can be applied to the atmospheric, splash, and underwater zones by troweling the two-component jacket in place. Divers wearing rubber gloves can apply this material underwater. Both atmospheric and underwater surfaces can be prepared by sandblasting techniques.[11]

Protective Coatings Other Than Jacketing. When jacketing is not considered cost-effective, the sheet piles should be coated on the atmospheric, splash, and immersed zones according to the painting schedule below:

Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Sandblast to near white grade, SSPC-SP-10[12]	Coal-tar epoxy	SSPC Paint 16	SSPC Paint 16	
		(Two coats with a minimum dry film thickness of 16 mils.)		
	Epoxy	MIL-P-24441*	MIL-P-24441	MIL-P-24441
		(Three coats to an average DFT of 7.0 mils.)		
	Thin film fusion-bonded epoxy	The coating shall be factory applied to achieve a holiday-free coating with a minimum total dry film thickness of 8.0 mils.		

Second and third coats of these epoxies should be applied after the previous coat has become firm, but before it has completely cured, i.e., within 24 hr if curing at 70°F and within 8 to 16 hr if curing at temperatures above 100°F.

[11]R. W. Drisko, J. W. Cobb, and R. L. Alumbaugh, *Underwater Curing Epoxy Coatings*, Technical Report R300 (U.S. Naval Civil Engineering Laboratory [NCEL], May 1964).

[12]SSPC-SP 10, "Near White Blast Cleaning," *Steel Structures Painting Manual, Volume 2—Systems and Specifications*, 2nd ed. (Steel Structures Painting Council [SSPC], 1982).

*Department of Defense Standards.

Rehabilitation of Corroded Sheet Metal

Rehabilitation of corroded, in-service sheet piling should include the application of special polyamide-cured epoxies that will cure where moisture is present and even underwater.[13] In general, the special epoxies require a sandblasted surface finish. The epoxies can also be used to repair damaged coal-tar epoxy.

SOGS Section No. 02455: Aircraft Tie-Down Anchors

Environment - Exposure	*Materials Selection*
Coastal/inland - Soil	Copper alloy no. C69400.
Coastal/inland - Soil	Copper alloy no. C69430.
Coastal/inland - Soil	Copper alloy no. C69440.
Coastal/inland - Soil	Copper alloy no. C69450. All copper alloys to be used in corrosive soils should have cathodic protection.

Cathodic Protection

All aircraft tie-down anchors, including copper-covered steel anchors, should have cathodic protection using properly sized sacrificial zinc anodes if the anchors will be exposed to soils aggressive to copper-based alloys. In general, copper and copper-based alloys can be cathodically protected in most soils using less than 5 mA of current for each square foot of exposed metal.[14]

Soils known to be aggressive to copper and many of its alloys (i.e., along the coast in Saudi Arabia) include those which are damp and have: (1) high sulfates and/or chlorides; (2) very low resistivities (less than about 500 ohm-cm); (3) high organic contents (particularly organic acids); (4) cinders; (5) poor aeration and support for anaerobic bacterial activity; (6) ammonia or ammonia-containing compounds; (7) inorganic acids; and/or (8) small quantities of sulfide.[15]

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[13] R. W. Drisko, J. W. Cobb, and R. L. Alumbaugh; R. W. Drisko and C. V. Brouillette, "Protective Coatings in Shallow and Deep Ocean Environments," paper presented at Western Region Conference, National Association of Corrosion Engineers (NACE), Honolulu, HI (November 1965).

[14] O. W. Zastro, "Galvanic Behavior of Underground Cable Neutral Wires and Jacketing Materials," *Materials Performance*, Vol 16, No. 11 (November 1977), pp 18-21.

[15] J. R. Myers and A. Cohen, "Underground Behavior of Copper Water Tube," paper presented at the Annual Meeting of the American Water Works Association (AWWA), Miami, FL (May 1982).

SOGS Section No. 02618: Pavement Markings (Airfields and Roads)

Component	*Environment - Exposure*	*Materials Selection*
Asphaltic pavements	Coastal/inland	TT-P-1952.
Concrete pavements	Coastal/inland	TT-P-1952 or TT-P-85.
Reflective spherical glass beads for reflective paint	Coastal/inland	TT-B-1325, Type 111, gradation A. (Note: beads must be kept dry; those sticking together should be discarded rather than reclaimed).[16]

Surface Preparation

New pavement surfaces shall be allowed to cure no less than 30 days before applying masking materials.[17] Before painting over existing markings, all loose paint should be removed from the surface to be marked by water blasting or mechanical methods. Concurrently, all chalk should be removed, especially when TT-P-1952 is to be applied as the overlay. The total paint accumulation for a marking system should never exceed four coats before it is removed completely.

Application

Paints should not be thinned before application, especially when beads are to be applied, because thinning could adversely affect the beads' embedment depth. Both TT-P-85 and TT-P-1952 should be applied at a rate of 100 to 110 sq ft/gal. This application corresponds to wet and dry film thicknesses of about 0.015 and 0.007 to 0.008 in., respectively. The TT-B-1325 beads for TT-P-85 and TT-P-1952 paints should be applied at 10 lb/gal paint.

Paint should not be applied during high winds, high humidities, low temperatures (less than 40°F for TT-P-85 and less than 50°F for TT-P-1952), or high temperatures (i.e., when the pavement temperature exceeds about 95°F). Paint temperatures shall be maintained within these same limits. Application outside these limits should be allowed only if it can be demonstrated that adverse effects will not result (e.g., premature cracking or lifting of the paint, poor adhesion of the reflective beads, cracking and lifting of the substrate).

[16]R. W. Drisko, Techdata Sheet No. 79-05 (NCEL, Naval Construction Battalion Center, Port Hueneme, CA, April 1979).

[17]Corps of Engineers Guide Specification (CEGS)-02577, *Pavement Markings (Airfields and Roads)* (U.S. Army Corps of Engineers [USACE], Office of the Chief of Engineers [OCE], January 1983).

SOGS Section No. 02711: Fence, Chain-Link

Component	*Environment - Exposure*	*Materials Selection*
Fence, chain-link	Coastal (1500 ft or less from shoreline)*	PVC clad/coated galvanized steel.[18] The coating system should consist of zinc galvanizing of 2 ± 0.1 oz zinc/sq ft with a 0.020-in.-thick PVC coating thermally fused and bonded to a primer, which is thermally cured onto the zinc galvanizing.
Fence, chain-link	Coastal (greater than 1500 ft from shoreline)	Polyvinyl chloride clad/coated galvanized steel. The coating system should consist of zinc galvanizing of 1.0 ± 0.1 oz zinc/sq ft with a minimum 0.007-in-thick PVC coating thermally fused and bonded to a primer, which is thermally cured onto the zinc galvanizing.
Fence, chain-link	Inland - Dry atmosphere	Galvanized steel meeting RR-F-191/1C, Type I, zinc-coated steel wire, minimum 1.2 oz of zinc per sq ft of coated surface.
Posts, gates, chain, wire rope, clamps, and accessories	Coastal (1500 ft or less from shoreline)	Same as fence, chain-link.[19]
Posts, gates, chain, wire rope, clamps, and accessories	Coastal (greater than 1500 ft from shoreline)	Same as fence, chain-link.

*Based on International Nickel Co. (INCO) data from exposure at Wrightsville Beach, NC.

[18]E. S. Matsui, *Protection of Fencing Materials in a Marine-Atmosphere Environment*, Techdata Sheet No. 72-02 (NCEL, Port Hueneme, CA, September 1972).

[19]E. S. Matsui, *PVC-Coated Posts and Accessories for Chain-Link Fences*, Techdata Sheet No. 76-16 (NCEL, Port Hueneme, CA, September 1976); K. Gray, *Reinforcement System for Chain-Link Gates*, Techdata Sheet 78-40 (NCEL, Port Hueneme, CA, July 1978).

Component	*Environment - Exposure*	*Materials Selection*
Posts, gates, chain, wire rope	Inland - Dry atmosphere	Polyurethane-coated galvanized steel. The coating system is (1) zinc galvanizing of 1.0 + 0.1 oz zinc/sq ft, (2) chromate of 30 ± 15 mg/sq in., (3) clear crosslinked acrylic polyurethane coating. Thickness of the clear coating shall be approximately 0.0005 ± 0.0002 in. (Note: the above system is for nonvinyl-coated items. The chromate conversion and clear polyurethane coatings should not be specified for vinyl-coated items because they may interfere with the vinyl's bonding.)

SOGS Section No. 02712: Fence, Barbed-Wire

Component	*Environment - Exposure*	*Materials Selection*
Fence, barbed-wire	Coastal (1500 ft or less from shoreiine)	Polyvinyl chloride clad or coated galvanized steel wire with 5052 aluminum alloy barbs. See **SOGS Section No. 02711: Fence, Chain-Link** for coating system details.
Fence, barbed-wire sawtooth-type concertina	Coastal (1500 ft or less from shoreline)	Type 201 stainless steel.
Posts, bracing members, and stay wires	Coastal (1500 ft or less from shorline)	Polyvinyl chloride clad or coated galvanized steel. See **SOGS Section No. 02711** (posts, etc.) for coating system details.

Component	*Environment - Exposure*	*Materials Selection*
Fence, barbed-wire	Coastal (greater than 1500 ft from shoreline)	Polyvinyl chloride clad or coated galvanized steel wire with 5052 aluminum alloy barbs. See **SOGS Section No. 02711: Fence, Chain-Link** for coating system details.
Fence, barbed-wire, sawtooth-type concertina	Coastal (greater than 1500 from shoreline)	Type 201 stainless steel.
Fence, barbed-wire	Inland - Dry	Polyvinyl chloride clad or coated galvanized steel wire with 5052 aluminum alloy barbs. See **SOGS Section No. 02711: Fence, Chain-Link** for coating system details.
Fence, barbed-wire, sawtooth-type concertina	Inland - Dry	Type 201 stainless steel.
Posts, bracing and stay wires	Coastal (greater than 1500 ft from shoreline)	Polyvinyl chloride members, clad or coated galvanized steel. See **SOGS Section No. 02711** (posts, etc.) for coating system details.
Posts, bracing members, and stay wires	Inland - Dry	See **SOGS Section No. 02711** (posts, etc.) for material selection.

Grounding

When security fences must be grounded, solid copper rods and straps should be used. The ground rod-to-soil potential should be surveyed annually to determine where, if any, active corrosion of underground copper is occurring. This survey should be in addition to the routine ground-resistance measurements to ensure proper grounding of the security fences.

5 CONCRETE AND METALS

SOGS Section No. 03316: Concrete for Building Construction

Component	*Environment - Exposure*	*Materials Selection*
Concrete	Coastal/inland - Atmospheric	Concrete mix containing less than 0.8 lb chloride (Cl^{-1}) per cubic yard of concrete with a water-to-cement ratio of 0.4 to 0.5.[20]
Concrete	Coastal/inland - Contacting soil with sulfide (S^{-2}) content greater than 75 mg/kg of air-dried soil or a sulfate (SO_4^{-2}) content greater than 2500 mg/kg of air-dried soil	Type V plus Pozzolan cement.[21] Type V Portland cement (ASTM C 150-86).[22]
Steel reinforcement	Coastal/inland - Concrete expected to contain greater than 0.8 lb chloride (Cl^{-1}) per cubic yard of concrete	Fusion-bonded epoxy-coated reinforcement (ASTM D 3963-81).[23]
Bare steel reinforcement	Coastal/inland - Concrete containing less than 0.8 lb chloride (Cl^{-1}) per cubic yard of concrete	The concrete cover will be crack-free and have low permeability. The water-to-cement ratio of the mix will be less than 0.45. The concrete cover will be greater than 2.5 in. and the mix will be formulated with a calcium nitrite inhibitor. (American Concrete Institute [ACI] Standard No. 318).[24]

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[20] C. Hahin, "Corrosion-Resistant Design Guidelines for Portland Cement Concrete," paper presented at Corrosion/83, Anaheim, CA (April 1983).

[21] *Building Code Requirements for Reinforced Concrete*, ACI 318-83 (American Concrete Institute [ACI], Detroit, MI, November 1983), p 16.

[22] ASTM C 150-86, "Specification for Portland Cement," *ASTM Standards* (1983).

[23] ASTM D 3963-81, "Epoxy-Coated Reinforcing Steel," *ASTM Standards* (1983).

[24] C. Hahin; D. Whiting, "Concrete Materials, Mix Design, Construction Practices, and Their Effects on the Corrosion of Reinforcing Steel," paper presented at Corrosion/78, Houston, TX (March 1978); J. T. Lundquist, Jr., A. M. Rosenberg, and J. M. Gaidis, "Calcium Nitrite as an Inhibitor of Rebar Corrosion in Chloride-Containing Concrete," *Materials Performance*, Vol 18, No. 3 (March 1979), pp 36-40.

Component	Environment - Exposure	Materials Selection
Concrete coating	Coastal/inland - Soil with sulfide (S^{-2}) content greater than 75 mg/kg of air-dried soil or a sulfate content greater than 2500 mg/kg of air-dried soil[25]	Bitumastic coating, MIL-C-18480. A minimum coating thickness of 0.50 mm or 20 mils is required.[26]

Rehabilitation of Corroded Rebar

If there is rebar corrosion (e.g., as indicated by cracking or spalling and/or rust stains on the concrete) in buildings scheduled for rehabilitation, the weakened concrete should be removed. After removing all rust from the rebar surfaces mechanically, a zinc-rich organic coating should be applied to the exposed rebars before replacing the concrete. A breathable coating (e.g., TT-P-19 or TT-P-55) should then be applied to the concrete building's exterior surfaces. Concurrently, an impermeable coating should be applied to interior surfaces of the structure's outside walls.

SOGS Section Nos. 05020 and 05021:* Ultrasonic Inspection of Weldments and Ultrasonic Inspection of Plates

Ultrasonic inspection is an effective method for evaluating corrosion damage (e.g., stress-corrosion cracking)[27] and locating internal flaws and hidden crevices in welds.[28] However, limitations of this testing technique must be recognized, including:[29] (1) manual operation requires careful attention by experienced technicians; (2) extensive technical knowledge is required for developing inspection procedures; (3) components that are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect; (4) discontinuities in a shallow layer immediately under the surface may not be detected; (5) couplants are needed to provide effective transfer of ultrasonic wave energy between the transducers and the parts being inspected; and (6) reference standards are needed both for calibrating the equipment and characterizing flaws and defects.

The need for reference standards is especially important with regard to evaluating corrosion damage. Unless the testers know what they are looking for and have a reference standard for that flaw or defect, the problem may go totally undetected by even skilled operators.

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[25] D. Knofel, *Corrosion of Building Materials* (Van Nostrand Reinhold, New York, 1978), pp 17-22.

[26] D. Knofel.

*These SOGS are combined because the corrosion control recommendations follow the same guidelines.

[27] "Ultrasonic Inspection," *Metals Handbook*, Vol 11 (American Society for Metals, Metals Park, OH, 1976), pp 161-198.

[28] "Nondestructive Inspection of Weldments," *Metals Handbook*, Vol 11 (American Society for Metals, Metals Park, OH, 1976), pp 340-355.

[29] "Ultrasonic Inspection."

SOGS Section No. 05120: Structural Steel

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric	All grades of structural steel should be aluminized for severely corrosive coastal environments with the structural members assembled using aluminized-steel fasteners.
Coastal - Atmospheric	All grades of structural steel should be galvanized for severely corrosive coastal environments with the structural members assembled using galvanized steel fasteners; with the galvanized steel overlaid with an organic coating (see **SOGS Section No. 09900**).
Inland - Atmospheric	All grades of structural steel. See **SOGS Section No. 09900** for organic coating system requirements.

General Notes

For all locations, designs should be used which: (1) provide for drainage where water would otherwise collect, (2) eliminate crevices, and (3) allow access to the structural members so they can be cleaned and coated during the life expectancy of the structure.[30]

Under no circumstances should naturally weathering steels (e.g., high-strength, low-alloy steels such as ASTM A 588-82) be considered for applications that will be exposed to chloride-containing, highly humid, or wet environments.[31]

SOGS Section No. 05141: Welding, Structural

Environment - Exposure	*Materials Selection*
Coastal/inland	Structural welds--all sharp protrusions and weld spatter shall be removed so the weld areas can be coated effectively.

[30] K. Treadway, "Corrosion of Steel in Buildings," *Bulletin of the Institute of Corrosion Sciences and Technology*, Vol 19, No. 4 (July 1981), pp 4-5.

[31] B. Paul, "Weathering Steel Prompts Big Debate," *American Painting Contractor*, Vol 60, No. 3 (March 1983), pp 35-36; "An Evaluation of Weathering Steel Bridges," *Rural and Urban Roads*, Vol 21, No. 5 (May 1983), pp 31-33; "Bridge Painting Cost Overrun Highlights Weathering Steel Woes," *The AHDGA Market News* (American Hot Dip Galvanizers Association [AHDGA], Washington, D.C., Winter/1983), pp 6-7.

SOGS Section No. 05210: Steel Joists

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric	Aluminized-steel joists for coastal and industrially polluted atmospheres.
Coastal - Atmospheric	Galvanized-steel joists for coastal and industrially polluted atmospheres; the galvanized steel should be overlaid with an organic coating system (see **SOGS Section No. 09900**).
Inland - Atmospheric	Galvanized-steel joists.

General Notes

For all locations, designs should be used which (1) prevent open-web steel joists from collecting water and dust/sand/salt and (2) eliminate crevices.

SOGS Section No. 05301: Roof Decking, Steel

Environment - Exposure	*Materials Selection*
Coastal/inland	Galvanized steel.

General Notes

When "nested" for overseas transport, the surfaces shall be chromate-treated and lightly oiled by the fabricator to prevent "white rust." Packaging for overseas shipment must include a heavy-duty waterproof wrapping and expandable steel shrouds on the package ends.

SOGS Section No. 05500: Miscellaneous Metal

Component	*Environment - Exposure*	*Material Selection*
Wire rope: antenna guys and associated hardware	Coastal	Type 304 stainless steel.
Wire rope: antenna guys and associated hardware	Coastal	Aluminized steel, preferably overlaid with a factory-applied organic coating (e.g., a UV-resistant vinyl).[32]

[32]J. R. Myers, *Preliminary Corrosion-Control Survey of King Faisal and King Abdulaziz Naval Bases, Saudia Arabia*, report prepared for HBH Company (Arlington, VA, October 1980).

Component	*Environment - Exposure*	*Materials Selection*
Wire rope: antenna guys and associated hardware	Inland	Galvanized steel.
Ladders and accessories	Coastal/inland	6061-T6 aluminum alloy.*
Fire escapes	Coastal/inland	Aluminized steel.*
Guard- and handrails	Coastal/inland	6061-T6 aluminum alloy for exterior and interior guard- and handrails at all locations; the aluminum alloy must never come into contact with wet concrete containing more than 0.5 lb chloride per cubic yard of concrete.
Floor gratings	Coastal/inland	Aluminized steel, 6061-T6 aluminum alloy, or brass.*

General Notes

1. All grades of stainless steel: Not recommended where they will be exposed to quiescent seawater or wet soils containing more than 250 mg/L chloride.[33]

2. All grades of aluminum alloys: Not recommended where the environment will have a pH greater than 8.5 or less than 6.5.

3. Zinc alloys: Not recommended for coastal or industrially polluted atmospheres.

4. Copper and copper alloys: Not recommended for aqueous environments where these metals/alloys will be upstream of aluminum and zinc (including their alloys).

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*Fiberglass reinforced plastic ladders, floor gratings, walkways, manhole covers, doors, etc., for exterior exposure (or interior high-salt-level exposures) should be used wherever possible. Items for exterior exposures must be suitably formulated or coated to protect against ultraviolet (UV) degradation. Ladders, floor gratings, walkways, and manhole covers must be coated with a material that can withstand the UV exposure and personnel foot traffic. Fiberglass items may have a higher initial cost but should prove more cost-effective in the long run due to lower maintenance needs.

[33]V. C. Peterson and D. Tamor, "Tests Show How Seawater Affects Wire-Strand and Rope," *Materials Protection*, Vol 7, No. 5 (May 1960), pp 32-34.

6 THERMAL AND MOISTURE PROTECTION

SOGS Section No. 07112: Bituminous and Elastomeric Waterproofing

Environment - Exposure	*Materials Selection*
Coastal/inland	Bituminous-saturated cotton fabric applied continuously on the suitably primed walls and floor of a basement using the number of plies required to achieve the desired objective (minimum of three), with the number of moppings exceeding the number of plies by one.
Coastal/inland	Bituminous-saturated felt applied continuously on the suitably primed walls and floor of a basement using the nu..iber of plies required to achieve the ' ;ired objective (minimum of ıree), with at least one of the plies being bituminous-saturated cotton fabric and the number of moppings exceeding the number of plies by one. The minimum weight of bituminous-saturated felt used in a membrane should be 13 lb/100 sq ft. The minimum weight of bituminous-saturated woven cotton fabric should be 10 oz/sq yd.
Coastal/inland	Butyl rubber consisting of a continuous 0.07- to 0.13-in.-thick layer secured with a compatible adhesive.[34]

[34] F. S. Merritt (Ed.), *Building Construction Handbook* (McGraw-Hill, New York, 1975), Ch 12, pp 9-12.

Materials

Materials used in the membrane should meet the requirements of the following current ASTM standards:[35]

Materials	ASTM Standard
Creosote Primer for Coal-Tar Pitch	D 43-73
Primer for Asphalt	D 41-78
Coal-Tar Pitch	D 450-78
Asphalt	D 449-79
Woven Cotton Fabric, Bituminous-Saturated	D 173-81
Coal-Tar-Saturated Felt	D 227-82
Asphalt-Saturated Felt	D 226-82

Application of Membrane

Asphalt shall not be heated higher than 425°F for Type II and 475°F for Type III, and in no case within 50°F of the flash point. Coal-tar bitumen shall not be heated above 425°F. Flash point temperature shall be posted conspicuously on the kettle. Kettlemen shall be in attendance at all times during the heating to ensure that the maximum temperature is not exceeded. Asphalt shall be applied within a range of 325°F to 375°F for Type II and 375°F to 425°F for Type III. Coal-tar bitumen shall be applied within a range of 350°F to 400°F. Bitumen at a temperature below this range shall be returned to the kettle. Bitumen shall be applied uniformly at a rate for each ply of 15 to 20 lb of asphalt or 20 to 30 lb of coal-tar bitumen/100 sq ft. Felt or fabric shall be rolled or pressed firmly into the hot bitumen to eliminate air pockets, wrinkles, or similar deficiencies. Plies shall be applied in shingle fashion and the felt or fabric shall be coated thoroughly. The entire top surface shall be given a final mopping of no less than 60 lb asphalt or 70 lb coal-tar bitumen/100 sq ft.

SOGS Section No. 07140: Metal-Oxide Waterproofing

Metal- (iron) oxide-type waterproofing products may or may not be effective. Some data suggest that trowel-applied mortar coatings are highly water-resistant whether or not they contain iron.[36]

Coatings that contain iron are permeable to water penetration by capillary action whether or not the water is under hydrostatic head.[37] Thus, this type of coating is not

[35]ASTM D 43-73, "Specification for Creosote Primer Used in Roofing, Dampproofing, and Waterproofing"; ASTM D 41-78, "Specification for Asphalt Primer Used in Roofing and Waterproofing"; ASTM D 450-78, "Specification for Coal-Tar Bitumen Used in Roofing, Dampproofing, and Waterproofing"; ASTM D 449-79, "Specification for Asphalt Used in Dampproofing and Waterproofing"; ASTM D 173-81, "Specification for Bitumen-Saturated Cotton Fabrics Used in Roofing and Waterproofing"; ASTM D 227-82, "Specification for Coal-Tar Saturated Organic Felt Used in Roofing and Waterproofing"; ASTM D 226-82, "Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing," *ASTM Standards* (1983).

[36]F. S. Merritt (Ed.), Ch 12, p 3.

[37]F. S. Merritt (Ed.), Ch 12, p 3.

"waterproofed" in the full sense. In general, iron-containing products should be avoided as waterproofing agents.

Cementitious coatings with crystallization can be used for interior application below grade provided there is minimal crack movement and moderate water pressures (less than 15 ft head). These types of coatings are especially valuable for maintenance or rehabilitation work.

SOGS Section No. 07141: Metal Roofing and Siding, Plain

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric	Aluminized steel.
Inland - Atmospheric	Galvanized steel.

General Comments

All design details must be reviewed carefully to ensure that thermal expansion and contraction of the panels and other items are not hindered in any way. Metal roofing and siding components must be allowed to move freely while sealing against the weather.

Uncoated galvanized-steel roofing and siding should be restricted to inland locations that have no industrial pollution in the atmosphere. Uncoated aluminized steel is acceptable for roofing and siding at coastal and industrial sites. However, it eventually will require coating. The surface preparation and inability to coat critical areas of the building components at this later date may lower the coating's effectiveness. If possible, only coated aluminized-steel roofing and siding should be used in aggressive environments (see **SOGS Section No. 07142**).

SOGS Section No. 07142: Metal Roofing and Siding, Factory Color-Finished

Environment - Exterior Exposure	*Materials Selection*
Coastal/industrial - Atmospheric	Aluminized steel coated with an oven-baked fluoropolymer enamel (see **SOGS Section No. 13602**).
Inland - Atmospheric	Galvanized steel coated with an appropriate oven-baked enamel (see **SOGS Section No. 13602**).

General Comments

All design details must be reviewed carefully to ensure that thermal expansion and contraction of the panels and other items are not hindered in any way. Metal roofing and siding components must be allowed to move freely while sealing against the weather.

SOGS Section No. 07160: Bituminous Damp-Proofing

Environment - Exposure	*Materials Selection*
Coastal/inland	Asphalt, ASTM D 449-79, Type III, with flash point stated on the wrapper or delivery ticket. Use where dampproofing would be exposed to temperatures greater than 125°F after application.
Coastal/inland	Asphalt, ASTM D 449-79, Type II, with flash point stated on the wrapper or delivery ticket.
Coastal/inland	Fibrous asphalt, ASTM D 2823-75.[38]

Bituminous Cutbacks

Bituminous cutbacks are not recommended for direct application to the inside faces of permeable masonry walls which are not plastered.[39] They can provide some benefit when incorporated into the masonry or held in place with rigid self-sustaining backing; they also may be of benefit as a vapor barrier in furred walls if no condensation occurs on the warm side.[40]

Hot Application Method

Surfaces to be dampproofed shall be given two mopped coats of hot asphalt. The mop coats shall be applied in a smooth, uniform, and continuous coating using no less than 20 lb asphalt/100 sq ft for each coat. Application temperature of the asphalt shall be between 325°F and 375°F for Type II and between 375°F and 425°F for Type III. Asphalt at a temperature below this range shall be returned to the kettle. Maximum kettle temperature shall be 425°F for Type II and 475°F for Type III asphalt, but in no case higher than 50°F below the flash point. Flash point temperature shall be posted conspicuously on the kettle. Kettlemen shall be in attendance at all times during the heating to ensure that the maximum temperature is not exceeded. Asphalt shall be fully bonded to the primed surface. The finished surface shall be smooth, lustrous, and impervious to moisture. Dull or porous spots shall be recoated.

[38] ASTM D 2823-75, "Specification for Asphalt Roof Coatings," *ASTM Standards* (1983).
[39] F. S. Merritt (Ed.), Ch 12, p 7.
[40] F. S. Merritt (Ed.), Ch 12, p 7.

SOGS Section No. 07600: Sheet Metalwork, General

Surface/ Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Aluminum in moderate to severely corrosive environments	Solvent Clean, SSPC-SP-1[41]	Aluminum	TT-P-645	TT-P-38	TT-P-38
Aluminum in moderately corrosive environments	Solvent Clean, SSPC-SP-1	Gloss, General Purpose	TT-P-645	TT-E-489 Class A or SSPC Paint 21, Type I	TT-E-489 Class A or SSPC Paint 21, Type I
		Gloss, Sunlight Resistant	TT-P-645	TT-E-1593	TT-E-1593

SOGS Section No. 07810: Skylights

Environment - Exposure	*Materials Selection*
Coastal/inland	Polymethyl methacrylate (PMMA). Organic solvents and abrasive cleaning agents must not be used to clean the PMMA.[42]

SOGS Section No. 07840: Ventilators, Roof: Gravity Type

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric	3000-series aluminum alloys, preferably with the alloys anodized.
Coastal - Atmospheric	6000-series aluminum alloys, preferably with the alloys anodized.

[41] SSPC-SP-1, "Solvent Cleaning," *Steel Structures Painting Manual Volume 2—Systems and Specifications*, 2nd ed. (SSPC, 1982).
[42] D. Knofel, p 95.

Environment - Exposure	*Materials Selection*
Coastal - Atmospheric	Aluminized steel, preferably overlaid with a suitable organic coating system (see **SOGS Section No. 09900).**
Inland - Atmospheric	Galvanized steel.

SOGS Section No. 07951: Calking and Sealants*

Environment - Exposure	*Materials Selection*
Coastal/inland	See *General Comments.*

General Comments

Although concrete structures can be coated easily, coating systems often fail because of sealant failure at the joints. Joint sealants for concrete panels should be mastics or elastomeric materials that are extensible and can accommodate panel movement. Recommended design joint widths for precast concrete panels are:[43]

Maximum Panel Dimensions (ft)	Normal Joint Width (in.)
5	0.38
18	0.5
30	0.75

Recommended maximum joint widths and maximum movements for various sealants are:[44]

Sealant Type	Maximum Movement, Maximum Joint Width (in.)	Tension and Compression (percent)
Acrylic	0.75	± 15 to 25
One-part polyurethane	0.75	± 20
Two-part polyurethane	0.75	± 25
One-part polysulfide	0.75	± 25
Two-part polysulfide	0.75	± 25

A major limitation of butyl sealants and calks is their susceptibility to ultraviolet degradation.[45] For this reason, they should not be used at most Middle East sites because of the bright sunlight.

*Calks are used for fixed joints or those with slight movement; sealants are used mainly for joints where movement is anticipated.

[43]F. S. Merritt (Ed.), Ch 5, p 107.

[44]F. S. Merritt (Ed.), Ch 5, p 107.

[45]G. E. Weismantel (Ed.), *Paint Handbook* (McGraw-Hill, New York, 1981), Ch 5, p 11.

Effective calking is important in preventing the ingress and accumulation of water in coated wood and cementitious substrates. Water or other moisture accumulation in these substrates must be minimized because it would ultimately cause the coatings to peel.

All sealants should be applied beginning at the bottom of the joint crevice and gradually building up to eliminate trapped air or voids.

7 DOORS AND WINDOWS

SOGS Section No. 08105: Steel Doors and Frames

Component	*Environment - Exposure*	*Materials Selection*
Steel door and frame	Coastal - Exterior	Aluminized steel, preferably factory-coated with an oven-baked fluoro-polymer enamel.
Steel door and frame	Coastal - Exterior	Galvanized steel, factory-primed with two coats of MIL-P-26915; topcoated with two coats of MIL-C-83286 after installation and primer touchup.
Steel door and frame	Inland - Exterior	Galvanized steel.
Hardware	Coastal/inland	Type 304 stainless steel.

SOGS Section No. 08201: Wood Doors

Component	*Environment - Exposure*	*Materials Selection*
Wood doors	Coastal/inland	Factory-primed and topcoated with a quality alkyd enamel (colored doors) or stained and primed with a moisture-curing polyurethane (natural-finish doors). Doors that leave the factory unprimed are not recommended. See **SOGS Section No. 09900** for coating system details.
Hardware	Coastal/inland	Type 304 stainless steel. 5000-series aluminum alloys; 6000-series aluminum alloys.

SOGS Section No. 08300: Miscellaneous Doors

Environment - Exposure	*Materials Selection*
Coastal/inland	Fiberglass doors--see *General Comments* below.[46]

[46] *Chem-Pruf Door Systems*, Technical Brochure No. 181-10 (Chem-Pruf Door Company, Brownsville, TX, 1981).

Environment - Exposure	*Materials Selection*
Coastal/inland	Aluminum-alloy doors, provided the aluminum alloys are insulated from steel, copper, and copper alloys in coastal and industrially polluted atmospheres. The aluminum alloys also should not contact wet mortar/concrete containing chlorides.
Coastal/inland	Steel doors, galvanized and factory-primed with two coats of MIL-P-26915; top-coated with two coats of MIL-C-83286 after installation and primer touchup.
Coastal/inland	Aluminized steel doors, preferably with a factory-applied oven-baked fluoro-polymer enamel.
Inland	Galvanized steel.
Coastal/inland	Hardware--Type 304 stainless steel;[47] 5000-series aluminum alloys; 6000-series aluminum alloys.

General Comments

For highly humid coastal locations, consideration should be given to using fiberglass-reinforced plastic (FRP) doors and frames with the associated hardware (hinges, screws, bolts, handles, kick plates, push plates, closers, thresholds, panic doors, and locksets) manufactured from Type 304 stainless steel.[48] The doors should be factory-mounted in the frames. FRP doors for which the inner cavities are filled with polyurethane foam should have an energy-efficient R factor of 9.[49] FRP doors are available with a flame-spread rating of less than 25 according to ASTM E 84-81a,[50] and satisfy the self-extinguishing requirements of ASTM D 635-81.[51] These doors are especially advantageous for sanitary facilities because the sealed, nonporous outer resin does not support bacterial proliferation.

[47] *Chem-Pruf Door Systems.*

[48] *Chem-Pruf Door Systems.*

[49] R = 1/C, where C is a material's conductance. C values are listed in *Handbook of Fundamentals* (American Society of Heating, Refrigerating, and Air-Conditioning Engineers [ASHRAE], 1985).

[50] ASTM E 84-81a, "Test Method for Surface Burning Characteristics of Building Materials," *ASTM Standards* (1983).

[51] ASTM D 635-81, "Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position," *ASTM Standards* (1983).

SOGS Section No. 08371: Aluminum-Framed Sliding Glass Doors

Environment - Exposure	*Materials Selection*
Coastal/inland	Frames must be electrically insulated from galvanized steel, steel, copper, copper alloys, and wet concrete/mortar that contains chlorides. The contacting surface should be coated with: (1) TT-V-51 (asphaltic varnish) or (2) MIL-C-18480 (bituminous coating).

SOGS Section No. 08510: Steel-Framed Glass Windows

Component	*Environment - Exposure*	*Materials Selection*
Windows	Coastal/inland Atmospheric	Aluminized steel, preferably with the frames factory-coated with an oven-baked fluoro-polymer enamel prior to installation of the glass.[52]
Windows	Inland - Atmospheric	Galvanized steel.
Insect screen	Coastal/inland - Atmospheric	Aluminum-alloy mesh-cloth insect screen is recommended for aluminized-steel frames at all locations.
Insect screen	Coastal/inland - Atmospheric	Copper/copper alloy. Mesh-cloth insect screen is recommended for steel and galvanized steel frames provided the frames are factory coated with an oven-baked fluoro-polymer enamel prior to installing the screen (to avoid possible galvanic corrosion between the frame and the insect screen).

[52] L. L. Shreir (Ed.), *Corrosion*, Vol 2 (Newnes-Butterworth, London, 1976), Ch 14, p 26.

SOGS Section No. 08520: Aluminum-Framed Glass Windows

Component	*Environment - Exposure*	*Materials Selection*
Windows	Coastal/inland - Atmospheric	1100-series aluminum should be used. Frames must be electrically insulated from galvanized steel, steel, copper, copper alloys, and wet concrete/mortar containing chlorides. The contacting surface should be coated with: (1) TT-V-51 (asphaltic varnish), or (2) MIL-C-18480 (bituminous coating).[53]
Insect screen	Coastal/inland - Atmospheric	Aluminum mesh-cloth insect screen is recommended for aluminum frames.

SOGS Section No. 08710: Hardware, Builders' (General Purpose)

Component	*Environment - Exposure*	*Materials Selection*
Fasteners--screws bolts, nuts, washers	Coastal/inland - Atmospheric	Austenitic stainless steels.
Fasteners--nails, screws, bolts, nuts, washers	Coastal/inland - Atmospheric	Aluminum alloys.
Fasteners--nails, screws, bolts, nuts, washers	Coastal/inland - Interior	Galvanized steel.
Locks, latches, door trim, and accessories	Coastal/inland - Atmospheric	Austenitic stainless steels.
Locks, latches, door trim, and accessories	Coastal/inland - Interior	Aluminum alloys.
Butts and hinges	Coastal/inland - Atmospheric	Austenitic stainless steel.
Butts and hinges	Coastal/inland - Interior	Copper alloys: brass or bronze.

[53]F. S. Merritt (Ed.), Ch 9, p 5.

SOGS Section No. 08711: Hardware, Builders' (for Permanent Hospitals)

Component	*Environment - Exposure*	*Materials Selection*
Fasteners--screws, bolts, nuts, and washers	Coastal/inland - Atmospheric/ interior	Austenitic stainless steels for high-use, high-sanitary areas.
Locks, latches, door trim, and accessories	Coastal/inland - Atmospheric/ interior	Austenitic stainless steels for high-use, high-sanitary areas.
Butts and hinges	Coastal/inland - Atmospheric/ interior	Austenitic stainless steels.
Butts and hinges	Coastal/inland - Interior	Copper alloys, brass or bronze for high-use areas, excluding those which must be highly sanitary.

8 FINISHES

SOGS Section No. 09100: Furring (Metal), Lathing and Plastering

Component	*Environment - Exposure*	*Materials Selection*
Furring (metal)	Coastal/inland - Interior	Hot-dip-applied galvanized steel.
Mortar	Coastal/inland - Interior	Gypsum for all locations in continuous contact with moisture-saturated air.[54]
Mortar	Coastal/inland - Interior	Anhydrite mortar for all locations except those in continuous contact with moisture-saturated air.[55]

General Comment

Decorative coatings should not be applied until the plaster has cured at least 30 days at a minimum temperature of 60°F.[56]

SOGS Section No. 09180: Stucco, Cement

Component	*Environment - Exposure*	*Materials Selection*
Steel reinforcement	Coastal/inland - Atmospheric	Hot-dipped galvanized steel, provided the cement will not contain/accumulate more than 0.8 lb chloride/cu yd cement at the reinforcements and that the reinforcements will be covered with a minimum of 2.5 in. concrete.

SOGS Section No. 09703: Conductive Sparkproof Industrial Resinous Flooring

Environment - Exposure	*Materials Selection*
Coastal/inland - Interior	Polyurethane binders should be used for flooring with heavy traffic.

[54]D. Knofel, pp 39-40.
[55]D. Knofel, pp 39-40.
[56]A. Banov, *Paints and Coatings Handbook* (Structures Publishing Co., Farmington, MI, 1973), p 124.

Concrete Surface Preparation

Surface preparation must include removal of hardening agents, waxes, resins, laitance, glaze, efflorescence, and other contaminants from the concrete surface. Hard, smooth concrete surfaces must be opened by acid etching prior to application of the flooring.[57]

SOGS Section No. 09900: Painting, General

Overview

To be effective, coatings for corrosion mitigation must be properly (1) selected, (2) specified, (3) applied to adequately prepared surfaces/substrates, and (4) allowed to cure. In general, multiple coats (with the product for each coat furnished by the same coating formulator) are required to achieve the desired dry film thickness (DFT); a waiting period between coats is usually required and there must be neither inadequate nor excessive wet-film application during a given coat. *Onsite inspection by properly trained personnel is mandatory during all phases of a coating project to ensure effective corrosion control.*

Whenever possible, products and techniques used during a coating project should be identified by standards and specifications that should be well known to those who will perform the work. For example, specifications for steel surface preparation should be those defined by either the Steel Structures Painting Council (SSPC)* or the National Association of Corrosion Engineers (NACE).** Visual standards available from both organizations provide an effective way while onsite to insure that the surface preparations specified have been obtained.

Equally important is that abrasive-blasted ferrous-metal surfaces in coastal and other aggressive environments are primed before any "rust-bloom" forms. To meet this requirement, personnel must prepare only as many abrasion-blast-cleaned surfaces as can be primed in a given work period. It should be noted that special products (e.g., silica sand or slag-based abrasives) are required for effective abrasive cleaning; do not use rounded sand (common in the Middle East) because the chloride content may be too high.

Rust-Inhibitive Coatings

"Rust-inhibitive coating" should be defined in the specifications as follows: "Rust-Inhibitive Coating--Coating used to prevent the corrosion of metals and, more particularly, specially formulated to prevent the rusting of iron, steel, and other metals."[58]

General Painting Schedule

A general painting schedule is given below. If any item is not listed in this schedule, check the appropriate SOGS section. Unless otherwise indicated, coatings should be applied at the spreading rates or dry film thickness recommended by the coating manufacturer.

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[57]G. E. Weismantel, Ch 11, p 21.

*Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213.

**National Association of Corrosion Engineers, 2400 West Loop South, Houston, TX 77027.

[58]J. R. Myers, *Fundamentals and Forms of Corrosion* (JRM Associates, Franklin, OH, 1974), pp 48-53.

General Painting Schedule

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Exterior stucco surfaces	Remove foreign matter, efflorescence, and loose particles, and roughen glazed surfaces	Flat	TT-P-19 or T-P-55, Type II	TT-P-19 or T-P-55, Type II	None None
		Heavy-duty	TT-P-95, Type II, Class 3	TT-P-95, Type II, Class 3	None
Exterior concrete masonry units	(See note A.) Dampen surface uniformly with potable water prior to the application of cement-emulsion filler	General-purpose flat	TT-F-1098 or A-A-1500	TT-P-19 or T-P-55, Type II	TT-P-19 or T-P-55, Type II
		General-purpose flat	Cement-emulsion filler	TT-P-19 or T-P-55, Type II	TT-P-19 or T-P-55, Type II
		Textured	TT-C-555, Type II	None	None
		Heavy-duty	TT-F-1098 or A-A-1500	TT-P-95, Type II, Class 3	TT-P-95, Type II, Class 3
Exterior structural clay tile	Remove foreign matter	Flat	TT-P-19	TT-P-19	None
		Textured	TT-C-555, Type II	None	None
Exterior concrete surfaces	(See note A)	Flat	TT-P-19	TT-P-19	None
		Textured	TT-C-555, Type II	None	None
Concrete walls and floors of swimming pools	(See note B.) First coat thinned with 1 part of approved thinner to 4 parts of paint by volume	General-purpose	SSPC Paint 19	SSPC Paint 19	SSPC Paint 19
		General-purpose	TT-P-95, Type I	TT-P-95, Type I	TT-P-95, Type I
Exterior asbestos-cement surfaces	Paint only dry, clean surfaces. Remove stains with solvents. No wire brushing.	Flat	TT-P-19	TT-P-19	None
Exterior wood surfaces not otherwise specified	(See note C)	Flat	MIL-P-28582 or TT-P-25	TT-P-19	TT-P-19
		(See note D)	MIL-P-28582 or TT-P-25	Two coats of exterior oil paint	

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Exterior wood surfaces as follow: steps, platforms, and floors of open porches	(See note C)	General-purpose	TT-E-487	TT-E-487	None
Exterior wood surfaces to receive natural finish	Remove foreign matter	Semi-transparent	TT-S-708	TT-S-708	None
		Opaque	TT-S-1992, Class B	TT-S-1992, Class B	None
Exterior hard-board, factory-primed	(See note C)	Flat	TT-P-19	TT-P-19	None
		(See note D)	Two coats of exterior oil paint.		None
Exterior ferrous surfaces, exposed, unless otherwise specified	Solvent-clean, commercial blast in accordance with SSPC-SP-6.[59] (See note E regarding selection of primers for ferrous surfaces)	Gloss, general-purpose	TT-P-86, Type II	TT-E-489, Class A	TT-E-489, Class A
		Gloss, general-purpose	SSPC Paint 25	TT-E-489, Class A	TT-E-489, Class A
		Gloss, sun-light-resis-tant	TT-P-86, Type II	TT-E-1593 or SSPC Paint 21, Type I	TT-E-1593 or SSPC Paint 21, Type I
		Gloss, sun-light-resis-tant	SSPC Paint 25	TT-E-1593 or SSPC Paint 21, Type I	TT-E-1593 or SSPC Paint 21, Type I
		Semigloss, general-purpose	TT-P-86, Type II	TT-E-529	TT-E-529
		Semigloss, general-purpose	SSPC Paint 25	TT-E-529	TT-E-529
		Semigloss, sunlight-resistant	TT-P-86, Type II	TT-E-490	TT-E-490
		Semigloss, sunlight resistant	SSPC Paint 25	TT-E-490	TT-E-490
		High-performance	MIL-P-38336 or MIL-P-26915, Type I, Class A	MIL-P-24441 (Minimum total dry film thickness of 5.0 mils.)	MIL-C-83286

[59] SSPC-SP-6, "Commercial Blast Cleaning," *Steel Structures Painting Manual Volume 2—Systems and Specifications*, 2nd ed. (SSPC, 1982).

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Exterior ferrous surfaces, shop-primed, exposed	Wire brush abraded or corroded spots and touch up with TT-P-86, Type II, or SSPC Paint 25. (See note E regarding selection of primers for ferrous surfaces.)	Gloss, general-purpose	TT-E-489, Class A	TT-E-489, Class A	None
		Gloss, sunlight-resistant	TT-E-1593 or SSPC Paint 21, Type I	TT-E-1593 or SSPC Paint 21, Type I	None
		Semigloss, general-purpose	TT-E-529	TT-E-529	None
		Semigloss, sunlight-resistant	TT-E-490	TT-E-490	None
Exterior ferrous surfaces subject to severe atmospheric conditions	Near white blast-cleaning, SSPC-SP-10	High performance vinyl, white or colored	SSPC Paint 9 (Four coats to obtain a minimum total dry film thickness of 5.0 mils.)		None
	Commercial blast-cleaning, SSPC-SP-6	Aluminum	TT-P-86, Type II	TT-P-38	TT-P-38
Exterior galvanized surfaces	Solvent clean, SSPC-SP-1, pretreat with SSPC Paint 27	High-performance vinyl, white or colored	SSPC Paint 9 (Four coats to obtain a minimum total dry film thickness of 5.0 mils.)		
		High performance urethane	MIL-P-26915 (Two coats)	MIL-C-83286	MIL-C-83286
		Gloss, general-purpose	TT-P-641, Type II or MIL-P-26915, Type I, Class A	TT-E-489, Class A	TT-E-489, Class A
		Gloss, sunlight-resistant	TT-P-641, Type II or MIL-P-26915, Type I, Class A	TT-E-1593	TT-E-1593
		Zinc gray	TT-P-641, Type II	TT-P-641, Type II	None
		Zinc gray	TT-P-1046	TT-P-1046	None
Exterior aluminum, aluminum alloy, and aluminized steel surfaces	Solvent clean, SSPC-SP-1, pretreat with SSPC-Paint 27	High-performance vinyl, white or colored	SSPC Paint 9 (Four coats to obtain a minimum dry film thickness of 5.0 mils.)		

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
	Solvent clean, SSPC-SP-1	Gloss, general-purpose	TT-P-645	TT-E-489, Class A	TT-E-489, Class A
		Gloss, sunlight-resistant	TT-P-645	TT-F-1593 or SSPC Paint 21, Type I	TT-E-1593 or SSPC Paint 21, Type I
		Aluminum	TT-P-645	TT-P-38	TT-P-38
Exposed interior oil-based calking compound	Allow compound to dry enough to form a surface skin before applying paint	General-purpose	TT-P-38	(Same as adjacent areas)	
Interior concrete floors	(See note A)	General-purpose	TT-P-91	TT-P-91	None
Interior concrete ceilings	(See note A)	Textured	TT-C-555, Type I	None	None
Interior concrete (except concrete floors and textured ceilings), masonry (except units with a porous surface), and structural clay tile	(See note A)	Flat	TT-P-29 or TT-P-650	TT-P-29	None
		Semi-gloss	TT-P-650 or TT-S-179	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509
		Semi-gloss	TT-P-29	TT-P-1511, Type I	None
		Textured	TT-C-555, Type I	None	None
Interior gypsum board, asbestos-cement board, composition fiberboard, unless otherwise specified	(See note A.) Seal gypsum board with TT-P-650 or TT-S-179	Flat	TT-P-650	TT-P-29	None
		Flat	TT-P-30	TT-P-30	None
		Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	None
		Semi-gloss	TT-P-1511, Type I	TT-P-1511, Type I	None
Interior plaster, unless otherwise specified	Age 30 days, surface shall be clean and free of loose matter and irregularities. Moisture content shall not exceed 8%	Flat	TT-P-650	TT-P-29	None
		Semi-gloss	TT-P-650 or TT-S-179	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509
		Semi-gloss	TT-P-29	TT-P-1511, Type I	None

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Interior concrete masonry units (with a porous surface)	(See note A)	Flat	TT-F-1098 or A-A-1500	TT-P-29	TT-P-29
		Semi-gloss	TT-F-1098 or A-A-1500	TT-P-29	TT-E-508 or TT-E-509
		Semi-gloss	TT-F-1098 or A-A-1500	TT-P-29	TT-P-1511, Type I
		Textured	TT-C-555, Type I	None	None
Interior concrete masonry units, plaster and gypsum board requiring liquid glaze	As stipulated in manufacturer's printed instructions	Liquid glaze	TT-C-550 (Number of coats in accordance with manufacturer's instructions)		
Interior concrete, concrete masonry, plaster, gypsum board in high traffic areas and in areas requiring a high degree of sanitation	(See note A.) Fill surfaces of concrete masonry units with TT-F-1098 or A-A-1500. Seal gypsum board and plaster with TT-P-650 or TT-S-179	Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	None
		Gloss	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506	None
	(See note A.) Fill surfaces of concrete masonry units with TT-F-1098 or A-A-1500	Heavy-duty	TT-C-535, Type II	TT-C-535, Type II	None
		Heavy-duty	TT-C-542, Type I or II, Class 2	TT-C-542, Type I or II, Class 2	None
Wood and metal interior trim, doors and windows (except in food-preparation, food-serving, shower, latrine, and laundry areas) and natural-finished wood surfaces	(See notes F and G)	Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	None
Interior hard-board surfaces	(See note F)	Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	None
Interior wood and metal interior trim, doors, and windows in food-preparation food-serving, shower, latrine and laundry areas (other than equipment, machinery, and natural-finished wood surfaces)	(See notes F and G)	Gloss	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506	None

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Interior exposed ferrous surfaces, unless otherwise specified	(See note G)	Flat	SSPC Paint 25	TT-P-30	TT-P-30
		Semi-gloss	SSPC Paint 25	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509
		Gloss	SSPC Paint 25	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506
		Aluminum	SSPC Paint 25	TT-P-38	TT-P-38
Interior unpainted ferrous surfaces in exposed areas having unpainted adjacent surfaces and in concealed damp spaces	Solvent cleaning and wire brushing; no pretreatment	Asphalt varnish	TT-V-51	None	None
Interior ferrous surfaces of mechanical and electrical equipment that has been factory-primed	Solvent clean as specified	Gloss	TT-E-489, Class A	TT-E-489, Class A	None
Interior ferrous surfaces of mechanical and electrical equipment that has been factory finished	Clean as required	To match existing surface	None (For damaged or scratched paint surfaces, spot-paint with factory-approved primer and topcoat)	None	None
Interior galvanized surfaces, unless otherwise specified	Solvent clean, SSPC-SP-1; pretreat with SSPC Paint 27	Variable	(Two coats of paint to match adjacent areas)		None
Interior wood surfaces (except floors) unless otherwise specified	(See note F)	Flat	TT-E-543 or TT-E-545	TT-P-30	TT-P-30
		Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	TT-E-508 or TT-E-509
		Gloss	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506	TT-E-505 or TT-E-506
Interior wood surfaces (except floors, handrails seats, and pews) to receive stain or natural finish	Clean and sand as required. Stain with TT-S-711 for shade as necessary	General-purpose varnish	TT-V-119	TT-V-119	TT-V-119
	Fill and seal as necessary	Low sheen varnish	TT-V-85	TT-V-85	TT-V-85

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
		Water-resisting varnish	TT-V-121	TT-V-121	TT-V-121
		General-purpose varnish	TT-V-109	TT-V-109	TT-V-109
Interior wood floors (except gymnasium floors) to receive stain or natural finish	(See note F)	Light use	TT-S-176, class as required	TT-S-176, class as required	P-W-158, Type II or P-W-155
		Polyurethane	TT-C-542, Type I, Class 1	TT-C-542, Type I, Class 1	P-W-158, Type II, or P-W-155
Interior wood floors to receive painted finish	(See note F)	Floor and deck enamel	TT-E-487	TT-E-487	None
Interior wood floors, factory-finished	Clean	Wax	P-W-158, Type II or P-W-155	None	None
Gymnasium floors	Clean as required	Polyurethane	TT-C-542, Type I, Class A	TT-C-542, Type I, Class A	None
Interior wood handrails	(See note F)	General-purpose	TT-V-119	TT-V-119	TT-V-119
		Water-resistant	TT-V-121	TT-V-121	TT-V-121
Seats and pews	(See note F)	General-purpose	TT-V-86	TT-V-86	None
Furniture and cabinetry	(See note F)	General-purpose urethane	TT-C-542, Type I, Class A	TT-C-542, Type I, Class A	None
Interior underside of zinc-coated and shop-primed steel roof decking where exposed in areas having painted walls	(See note G) Pretreat with SSPC Paint 27	Flat	TT-P-30	TT-P-30	None
		Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	None
		Gloss	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506	None
		Aluminum	TT-P-38	TT-P-38	None

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Radiators, convector enclosures, electrical conduit runs, metallic tubing, uninsulated ducts and pipes, pipe hangers, louvers, grilles, and air outlets in areas having painted adjacent surfaces	(See note G.) Prime as required	Gloss	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506	None
		Semi-gloss	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509	None
		Flat	TT-P-30	TT-P-30	None
Mastic-type surfaces, concrete, and plaster in refrigerated spaces	Remove foreign material	Flat	TT-P-19	TT-P-19	None
Wood and ferrous surfaces in refrigerated spaces	(See notes F and G)	Semi-gloss	TT-E-543 or TT-E-545	TT-E-543 or TT-E-545	TT-E-508 or TT-E-509
		Gloss	TT-E-543 or TT-E-545	TT-E-543 or TT-E-545	TT-E-505 or TT-E-506
		Heavy-duty	MIL-P-24441 (Two or more coats as necessary to obtain a minimum total dry film thickness of 4.0 mils.)		
Exterior or interior metal surfaces subject to high temperatures (up to 400°F)	Solvent cleaning and wire brushing; no pretreatment	Black	TT-E-496, Type II	TT-E-496, Type II	None
Exterior or interior metal surfaces subject to temperatures above 400°F (see note H for selection guidance)	White metal blast-cleaning, SSPC-SP-5,[60] no pretreatment	Inorganic zinc	MIL-P-38336 (For use up to 750°F)	MIL-P-38366	None
	Commercial blast-cleaning, SSPC-SP-6	Silicone aluminum	TT-P-28 (For use up to 1200°F)	TT-P-28	None
		Colors	MIL-P-14105 (For use up to 1400°F)	MIL-P-14105	None
Exposed-to-view pre-sized or adhesive finished glass cloth over insulation on pipes, ducts, and equipment, interior	Remove foreign matter	General-purpose	(Two coats to match adjacent areas)		None

[60] SSPC-SP-5, "White Metal Blast Cleaning," *Steel Structures Painting Manual Volume 2—Systems and Specifications*, 2nd ed. (SSPC, 1982).

General Painting Schedule (Cont'd)

Surface Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Chimney, masonry (obstruction painting)	(See note A)	Gloss, general-purpose	TT-P-24, Type I	TT-E-489 or SSPC Paint 21, Type I, white and international orange	None
Exposed insulating plank and tile roof decking	Remove foreign matter	Flat	TT-P-29	TT-P-29	None
Exposed mineral-wool gypsum and asbestos-cement formboard	Remove foreign matter	Flat	TT-P-19	TT-P-19	None

Note A (Concrete, Stucco and Masonry Surfaces): Surfaces shall be allowed to dry at least 30 days before painting. Glaze, efflorescence, laitance, dirt, grease, oil, asphalt, surface deposits of free iron, and other foreign matter shall be removed prior to painting. Immediately before coating with cement-emulsion filler, concrete-masonry-unit surfaces to be painted shall be uniformly and thoroughly dampened, with no free surface water visible, by several applications of potable water using a fog spray and allowing time between the sprayings for water to be absorbed. Concrete surfaces to be painted with moisture-cure polyurethane and epoxy coatings shall be acid-etched with 10 percent aqueous solution of muriatic acid, thoroughly rinsed with water, and dried. The dry concrete surface shall then be treated with the manufacturer's recommended conditioner prior to application of the first coat.

Note B (Walls and Floors of Swimming Pools): Surfaces should be clean, bare, and dry. New concrete surfaces should age for at least 2 months before being painted. Pool should be filled with water during this period to leach out the water-soluble salts, thus eliminating subsequent blistering of the paint. New concrete shall be prepared by removing all dirt, dust, efflorescence, oil and grease stains, or other foreign substances by wire or fiber brushing, scraping, light sandblasting, or other suitable means, followed by surface roughening when necessary to provide good adhesion. The surface should be allowed to dry before painting.

Note C (Exterior Wood): Wood surfaces to be painted shall be cleaned of foreign matter. Wood surfaces adjacent to surfaces to receive water-thinned paints shall be primed and/or touched up prior to the application of water-thinned paints. Small, dry, seasoned knots shall be scraped, cleaned, and given a thin coat of knot sealer, MIL-S-12935, before application of the priming coat. Pitch on large, open, unseasoned knots and all other beads or streaks of pitch shall be scraped off, or if still soft, removed with mineral spirits or turpentine and the resinous area thinly coated with knot sealer. Surfaces shall be checked to insure that finishing nails have been set properly and all holes and imperfections in finish surfaces shall be filled with putty or plastic wood filler, colored to match the finish coat if natural finish is required, allowed to dry, and sanded smooth. Painting shall proceed when the moisture content of the wood does not exceed 12 percent as measured by a moisture meter, unless otherwise authorized.

Note D: Exterior oil paint shall conform to the following Federal or Military Specifications: white, TT-P-102; light tints, TT-P-102; red or brown, TT-P-31; other deep colors, TT-P-37.

Note E: Red lead primer, TT-P-86, is the best primer for oil-based (enamel) paint systems used to protect atmospherically exposed mild steel. However, TT-P-86 has a lead content that far exceeds the 0.06 percent maximum lead content permitted by U.S. Public Law 94-317.[61] This limitation on lead-containing paints pertains only to all child-accessible interior and exterior areas of residential and institutional structures such as schools, nurseries, hospitals, and family housing. SSPC Paint 25 is a nontoxic alternative to TT-P-86 for use in these areas.

Note F (Interior Wood Surfaces): Interior wood surfaces to receive stain--including handrails, seats, and pews--shall be stained to the approved shade and sanded lightly. In addition, oak and other open-grain wood shall be given a coat of wood filler no sooner than 8 hours after the application of stain. Excess filler shall be removed and the surface sanded smooth.

Note G (Interior Ferrous Surfaces): Ferrous surfaces that have not been shop-coated shall be solvent-cleaned. Surfaces that contain loose rust, loose mill scale, and other foreign substances shall be cleaned mechanically by power wire brushing or sandblasting. Minor amounts of residual rust that cannot be removed except by thorough blast-cleaning and tight mill scale that cannot be removed by applying a sharp knife to any edge will be allowed to remain. The semitransparent film applied to some pipes at the mill is not to be considered a shop coat, but shall be overcoated with the specified first coat of paint. Shop-coated ferrous surfaces shall be protected from corrosion by treating and touching up corroded areas immediately upon detection.

Note H: MIL-P-14105 is a silicone frit, heat-resistant coating. It must be thermally cured prior to the formation of any visible corrosion products. Neglecting this curing process will lead to premature coating failure. This paint is typically applied at a DFT of 2.5 mils. Inorganic zinc-rich coatings must be applied over a white-metal blast finish. Aluminum silicone paint, TT-P-28, typically is applied with a DFT of 1.5 mils and must not be applied at a DFT greater than 4 mils. After painting, the coating should be baked at a temperature between 400 and 600°F for several hours or as recommended by the coating manufacturer.

[61] U.S. Public Law (PL) 94-317, *Public Health Service Act* (1976).

9 SPECIALTIES

SOGS Section No. 10160: Metal Toilet Partitions

Component	*Environment - Exposure*	*Materials Selection*
Metal toilet partitions	Coastal/inland - Interior	Metal toilet partitions should be covered with a chemical resistant, factory-applied coating system (e.g. epoxy-polyester).[62]
Partition hardware	Coastal/inland - Interior	Type 304 stainless steel.

SOGS Section No. 10801: Toilet Accessories

Environmental - Exposure	*Materials Selection*
Coastal/inland - Interior	Type 304 stainless steel for all accessories, with a No. 8 polish for mirrors.

SOGS Section No. 10910: Wardrobes

Component	*Environment - Exposure*	*Materials Selection*
Finish for natural-finished wardrobes	Coastal/inland - Interior	Stained and topcoated with TT-C-542, Type 1, Class A, urethane varnish (see **SOGS Section No. 09900**).
Hardware	Coastal/inland - Interior	Bronze and brass (solid), Type 304 stainless steel alloys. Bronze- and brass-plated steel--electro-deposited finish must have a minimum thickness of 0.0015 in.
Clothes-hanging rods	Coastal/inland - Interior	1110-series aluminum alloys.

[62] A. Banov, pp 28, 232-234, and 359-360.

10 EQUIPMENT

SOGS Section No. 11000: Miscellaneous Equipment

Component	*Environment - Exposure*	*Materials Selection*
Motor vehicles	Coastal/inland - Atmospheric	Factory-applied rustproofing using a high-pressure application technique with penetrants and sealants containing corrosion inhibitors wherein the areas identified in MIL-STD-1223W are rustproofed to the specified thicknesses of sealant and penetrant.

SOGS Section No. 11303: Sewage Lift Stations

Component	*Environment - Exposure*	*Materials Selection*
Coating system for steel lift station (or exposed steel components on concrete lift stations)	All locations	Epoxy-coated both internally and externally as given in the painting schedule below. All sewage side surfaces and external surfaces which contact corrosive soils shall be cathodically protected (see **SOGS Section Nos. 15605** and **16640**).
Concrete lift stations	All locations	Constructed using guidelines presented in **SOGS Section No. 03316.** Sewage side surfaces shall be coated with an epoxy coating system as given below.
Ladders	All locations	FRP with steel-reinforced FRP rungs cast in place on the concrete stations.
Pumps and pump components	All locations	Use guidelines presented in **SOGS Section No. 15140.**

Painting Schedule for Sewage Lift Stations

Surface/ Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
All steel	Near white blast-cleaning, SSPC-SP-10	Epoxy	MIL-P-24441 (primer)	MIL-P-24441 (Three coats to an average DFT of 7 mils.)	MIL-P-24441
		Epoxy, coal-tar	SSPC Paint 16 (Two or more coats as required for an average DFT of 16 mils.)		
Concrete, sewage-side surfaces	Clean and dry; new concrete aged at least 30 days	Epoxy	MIL-P-24441 (Two or more coats as required for an average DFT of 7 mils.)		
		Epoxy, coal-tar	SSPC Paint 16 (Two or more coats as required an average DFT of 16 mils.)		

SOGS Section No. 11701: Casework, Metal and Wood (for Medical and Dental Facilities)

Component	*Environment - Exposure*	*Materials Selection*
Wooden casework	Coastal/inland - Interior	Wooden casework should be finished as described for wardrobes (see **SOGS Section No. 10910**).
Coated-steel casework	Coastal/inland - Interior	All steel cabinet bases to be placed on floors that will be scrubbed periodically with detergent and water should be elevated approximately 1 in. above the floor by support frames made of a nonmetallic material. This design will prevent the steel from corroding due to water accumulation under the cabinets. Outer surfaces of all coated-steel cabinets should be cleaned and waxed at least once a year.

11 SPECIAL CONSTRUCTION

SOGS Section No. 13401: Incinerator, Rubbish and Garbage (Natural)

Component	*Environment - Exposure*	*Materials Selection*
Concrete foundations	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 03316.**
Sprayer equipment, including sprayers, expansion bolts/ nuts, sliding doors, hoods, vents, and associated components	Coastal/inland - Atmospheric	Aluminized steel (see guidelines in **SOGS Section No. 09900** for coating details).
Plumbing	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 15401.**
Hot-water storage	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 15401.**
Painting/ coating	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 09900.**
Fuel-oil storage tanks	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 15605.**

SOGS Section No. 13602: Metal Buildings (Enclosed)

Component	*Environment - Exposure*	*Materials Selection*
Structural steel beams and columns	Coastal/inland - Atmospheric	See guidelines in **SOGS Section Nos. 05120** and **09900.**
Concrete foundations	Coastal/inland - Atmospheric	See guidelines in in **SOGS Section No. 03316.**
Purlins	Coastal/inland - Atmospheric	Galvanized steel.

Component	*Environment - Exposure*	*Materials Selection*
Roof panels	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 07142.** Factory-finished sheets shall pass the following tests as detailed in the current SOGS No. 13602, Metal Building: salt spray resistance, formability, accelerated weathering, chalking resistance and color change, humidity resistance, and impact resistance. In addition, the coating must meet an abrasion resistance test: "When subjected to the falling sand test in accordance with ASTM D 968-81,[63] the coating system shall withstand a minimum of 100 L of sand before the appearance of base metal." Panels shall be a "standing-seam" interlocking design secured to the purlins by a concealed structural fastening system with concealed clips or backing devices used to fasten the roof panels to the purlins being fabricated from aluminized steel. "Standing seams" must have a factory-applied, nonhardening sealant and be locked or crimped together continuously by a mechanical method during erection. Exposed fasteners must penetrate through the roofing surface only at panel terminations; these fasteners must be stainless steel or aluminum-alloy screws, bolts/nuts, or rivets with weather-seal washers. Roof panel cross sections must be flat and free of cross-ribbing.

[63]ASTM D 968-91, "Test Method for Abrasion Resistance of Organic Coatings by the Falling Abrasive Tester," *ASTM Standards* (1983).

Component	*Environment - Exposure*	*Materials Selection*
Wall panels	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 07142.** Factory-finished sheets shall pass the following tests as detailed in the current SOGS No. 13602, Metal Building: salt spray resistance, formability, accelerated weathering, chalking resistance and color change, humidity resistance, and impact resistance. In addition, the coating must meet an abrasion resistance test: "When subjected to the falling sand test in accordance with ASTM D 968-81, the coating system shall withstand a minimum of 100 L of sand before the appearance of base metal." Wall panel seams must be interlocking, concealed, or tongue-and-groove type. Lap seams are not recommended. Wall panels must be fastened to their supports with clips, screws, or bolts/nuts inside the panels or concealed in the joints. Panel edges must not have external exposure.
Doors and frames	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 08105;** aluminized steel or FRP with Type 304 stainless steel hardware.
Windows	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 08510** (aluminized steel) and **SOGS Section No. 08520** (aluminum alloys).
Ventilators	Coastal/inland - Atmospheric	See guidelines in **SOGS Section No. 07840** (aluminized steel or 3000/6000-series aluminum alloys).

Component	*Environment - Exposure*	*Materials Selection*
Gutters	Coastal/inland - Atmospheric	Factory-applied, vinyl-coated aluminum alloys. Galvanized steel is not recommended.
Insulation	Coastal/inland - Atmospheric	Fiberglass with a permeability rating of 0.02 or less and containing no leachable halide ions.

12 MECHANICAL

SOGS Section No. 15116: Welding Pressure Piping

Environment - Exposure	*Materials Selection*
Coastal/inland - Atmospheric	Types 304L, 316L, 317L, 321, and 347 stainless steel where heavy-walled piping will be field-welded and subsequently exposed to coastal environments.

General Comments

Field-welding produces "sensitized" areas in heat-affected weld zones; these areas are susceptible to intergranular corrosion.[64] When possible, only low-carbon (e.g., Type 304L or 316L) or stabilized (e.g., Type 321 or 347) grades of austenitic stainless steel should be selected for field-welding.

Weld-related crevices must be avoided in all stainless steel components. Low-oxygen crevices can corrode rapidly, especially when chlorides accumulate there.[65]

Residual stresses associated with welding austenitic stainless steels must be minimized or eliminated if the pipes may be exposed to chloride-containing aqueous environments at temperatures above about 150°F.[66] Otherwise, stress-corrosion cracking may occur. Proper system design can be an effective way to minimize residual stress.

Welding of stainless steel in accordance with practices recommended by the American Welding Society (AWS) shall be used to achieve high-quality welds. Experience with construction welding of stainless steel at the U.S. Air Force (USAF) Arnold Engineering Center in Tennessee resulted in extensive problems, even when correct specifications were given (AWS D10.4-79).[67] To ensure effective welds, the contractor must follow specifications carefully and should avoid the following errors:

1. Weld spatter
2. Embedment of material such as iron chips and rust
3. Entrapment of slag in weld metal
4. Colored markings in welds
5. Splashing of paint near surfaces.

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[64] J. R. Myers, *Fundamentals and Forms of Corrosion.*

[65] H. Thielsch, *Defects and Failures in Pressure Vessels and Piping* (Krieger Publishing Co., Huntington, NY, 1977), pp 385-394.

[66] H. Thielsch.

[67] AWS D10.4-79, *Austenitic Chromium Nickel Stainless Steel Piping and Tubing, Recommended Practices for Welding* (American Welding Society [AWS], 1983).

SOGS Section No. 15140: Pumps: Sewage and Sludge

Component	*Environment - Exposure*	*Materials Selection*
Normal-duty sewage pumps for sewage not containing can lids and other cutting-type materials; shells and internal components	Coastal/inland - Sewage	Neoprene-coated ductile iron.
Heavy-duty sewage pumps:[68] stator housings, junction-box covers, impellers, rotating wear rings, and strainers	Coastal/inland - Sewage	Type 316 stainless steel.
Shafts		Types 420 and 431 stainless steel.
Grommets		Chloroprene rubber (60 IRH*).
Stationary wear rings		Nitrile rubber (40 IRH).
O-rings		Nitrile rubber (70 IRH).
Cooling jackets: for external surfaces of submerged areas		Type 304 stainless steel. Cathodic protection should be installed for all submerged surfaces (see **SOGS Section No. 16640**).
Sludge pumps: impellers, casings, and casing liners	Coastal/inland - Sludge	Ni-hard.**
Shaft sleeves and stuffing boxes		Type 316 stainless steel.
External surfaces of submerged areas		Cathodic protection should be installed for all submerged surfaces (see **SOGS Section No. 16640**).
Concrete foundations	Coastal/inland - Atmospheric	See **SOGS Section No. 03316.**

[68] *Flygt Product Education Manual* (Flygt Corporation, Norwalk, CT).

*IRH = International Rubber Hardness as defined in ASTM Standards.

**Tradename of INCO for a cast iron with nickel (4.5 percent nickel, 3.3 percent carbon, and 2.1 percent chrome).

SOGS Section Nos. 15141 and 15143:* Pumps: Water, Centrifugal Pump; Water, Vertical Turbine

Component	*Environment - Exposure*	*Materials Selection*[69]
Body suction bells, shrouds, liners, casings, discharge column, deepwell cans, impellers	Coastal/inland - Seawater and domestic waters containing more than 100 mg/L 100 mg/L chloride (as Cl^-)	Copper alloy no. 63000.
Wear rings		Ni-Cu alloy no. 506.
Shafts		Ni-Cu alloy no. 400.
Bolting		Ni-CU alloy no. 400.
Pump components contacting product water	Coastal/inland - Desalination plant product water	Type 304L stainless steel.[70] Aluminum bronzes.
Concrete pump foundations	Coastal/inland - Atmospheric	See **SOGS Section No. 03316.**[71]

General Comments

Figure 2 gives basic information on selecting pump materials for seawater service.

Types 304 and 316 stainless steel are not recommended for seawater service unless pumps operate continuously.

*These SOGS are combined because the corrosion control recommendations follow the same guidelines.

[69]T. E. Larson, "Corrosion in Vertical Turbine Pumps," *Water and Sewage Works*, Vol 94, No. 4 (April 1947); M. G. Fontana and N. D. Greene, *Corrosion Engineering* (McGraw-Hill, New York, 1978); *Materials for Seawater and Brine Recycle Pumps*, Technical Brochure No. 5M 11-76 (The International Nickel Company, Inc., New York, 1976).

[70]B. Todd, A. H. Tuthill, and R. E. Bailie, "Desalination--Lower Cost Water by Proper Materials Selection," paper presented at Third European Symposium on Fresh Water from the Sea, Dubrovnik, Yugoslavia (September 1970).

[71]An aluminum bronze containing about 4.5 percent nickel is needed to mitigate dealuminification according to F. W. Fink, *Alloy Selection for Heat Exchanger Service in Seawater Conversion Plants*, Technical Report No. 704/6 (Copper Development Association, Inc., 1966).

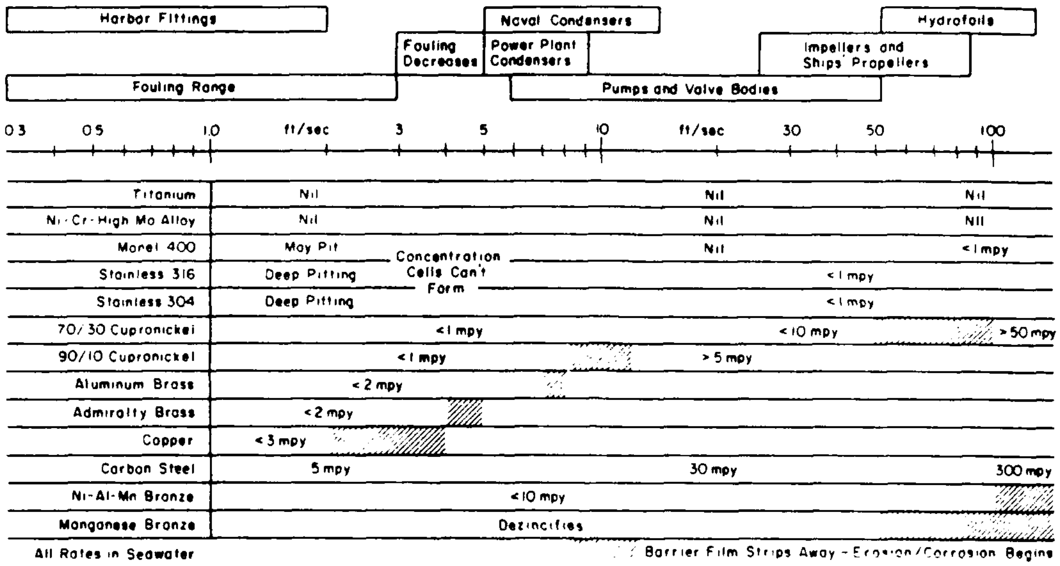

Figure 2. Effect of velocity on the corrosion and fouling of metallic materials in typical seawater, with corrosion rates given in mils/year. (From D. F. Hasson and C. R. Crowe, "Titanium for Offshore Oil Drilling," *Journal of Metals*, Vol 34, No. 1 [The Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers [AIME], Warrendale, PA, January 1982]. Used with permission.)

SOGS Section No. 15178: Pressure Vessels for Storage of Compressed Gases

Environment - Exposure	*Materials Selection*
Coastal/inland - Atmospheric	Types 304L, 316L, 321, and 347 stainless steel, not coated externally except where color coding is required.

General Comment

Types 304 and 316 stainless steel are not recommended for coastal atmospheres unless welds are suitably heat-treated to eliminate "sensitization."[72]

Halogenated cleaning agents are not acceptable for cleaning vessel interiors.[73]

Welds must be crevice-free without weld spatter and with no inclusions/slag in the weld metal. Welds will not be "buttered."[74]

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[72] J. R. Myers, *Fundamentals and Forms of Corrosion.*
[73] H. Thielsch, pp 370-420.
[74] H. Thielsch, pp 370-420.

SOGS Section No. 15201: Water Lines

Component	*Environment - Exposure*	*Materials Selection*
Cement-mortar-lined ductile iron	Coastal/inland - Soil	Coated and cathodically protected where exposed to aggressive soil that has a resistivity less than 5000 ohm-cm. See *General Comments.*
Copper water	Coastal/inland - Soil	Cathodically protected where tube exposed to aggressive soil.
Vinyl-lined concrete pipe	Coastal/inland - Soil	Coated externally where exposed to aggressive soil (see **SOGS Section No. 03316**).
PVC, PB, PE, and CVPC plastic pipe	Coastal/inland - Soil	Not recommended where the pipe can be accessed by gnawing rodents or where it will be directly exposed to ultraviolet radiation.[75]
Unlined asbestos-cement pipe	Coastal/inland - Soil	Not recommended.
Gray cast iron	Coastal/inland - Soil	Not recommended.
Steel and galvanized steel		Not recommended.

General Comments

Protective Coatings. All buried metallic piping or conduits, except copper, should be coated with coal-tar enamel or tape meeting American Water Works Association (AWWA)* Standard C-203,[76] factory-applied and -bonded PE, or factory-applied epoxy coatings (Federal Specification L-C-530, *Coating, Pipe, Thermoplastic Resin or Thermosetting [Epoxy]*). All field joints, valves, and similar items should be wrapped with hot-applied coal-tar tape as per AWWA C-203. Hot-applied coal-tar tape that meets AWWA C-203 is considered better than cold-applied protective tapes. However, the hot-applied tape's performance is very dependent on proper application. If there is concern for the quality of labor available, the next best choice is a prefabricated cold-applied tape, 50 mils thick, meeting AWWA C-209.[77] Tapecoat CT-10/40W, made by the

[75] D. A. Chasis, *Plastic Pipe Systems* (Industrial Press, Inc., New York, 1976), p 20.

*American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.

[76] AWWA C-203-78, "Pipeline Coatings and Linings," *AWWA Standards* (1978).

[77] AWWA C-209, *Cold-Applied Tape Coatings for Special Sections, Connections, and Fittings for Steel Water Pipelines* (AWWA Standards, 1976).

Tapecoat Company, Evanston, IL, meets these requirements. Tape wrap should be applied with care because high winds can blow sand onto primer, embedding the sand between tape and pipe. All underground metallic piping except copper should be cathodically protected in addition to being coated.

Polyethylene (PE) Encasement. PE encasement, as specified, is considered acceptable by the AWWA for gray and ductile cast-iron piping only and not for other buried pipe materials. Slip-on encasements used for the other metallic piping may actually accelerate corrosion, which cannot be mitigated effectively with cathodic protection. AWWA states the PE encasement is beneficial for cast-iron piping in corrosive soils. However, the adequacy of PE encasement for protecting ferrous piping against corrosion is still being evaluated due to conflicting data in the literature. Water can leak in between the pipe and encasement, causing corrosion. Once the oxygen is consumed, the corrosion is expected to stop; however, conditions then become favorable for anaerobic bacteria to destroy the pipe.[78] With thick-walled cast iron, this situation can go undetected because a graphite skeleton will be present even after the iron dissolves. However, the situation can be critical, because the pipe would have no strength left and could not withstand a surge of pressure. The encasement also foils future attempts to provide cathodic protection.

Asbestos-Cement and Concrete Pipe. Unlined asbestos-cement and concrete pipe should not be used to convey water that has an aggressive index (AI) less than about 10. The AI can be calculated using the expression:

$$AI = pH + \log (M \times CaH) \qquad \text{[Eq 1]}$$

where M is the total alkalinity and CaH is the calcium hardness, both expressed in milligrams per liter. For comparison, distilled water generally has an AI of less than 7. Water treatment can be used to raise the AI to a suitably high value (about 11) so that the cement will not leach; alternatively, vinyl-lined asbestos-cement or concrete pipe can be used.

Joint, Valves, and Similar Items. All field joints, valves, and similar items should be wrapped with hot-applied coal-tar tape meeting AWWA Standard C-203.

SOGS Section Nos. 15240 and 15241:* Elevated Steel Water Tanks; Steel Standpipes and Ground Storage Reservoirs

Component	*Environment - Exposure*	*Materials Selection*
Pipes and fittings (buried)	All locations	Ductile iron lined with cement mortar and coated on the outside surfaces (see **SOGS Section No. 15201).**

[78]C. K. Dittmer, R. A. King, and J. D. A. Miller, "Bacterial Corrosion of Iron Encapsulated in Polyethylene Film," *British Corrosion Journal*, Vol 10 (1975), pp 47-51.

*These SOGS are combined because the corrosion control recommendations follow the same guidelines.

Component	*Environment - Exposure*	*Materials Selection*
Concrete for foundations, ground storage reservoirs	All locations	See **SOGS Section No. 03316.** Concrete reservoirs can be coated as in the painting schedule below.
Coating system for interior surfaces of steel water tanks, standpipes, and tank risers	All locations	See painting schedule below. Risers with a diameter larger than 36 in. and all tank bowls and standpipes should also be cathodically protected (see **SOGS Section No. 16641**).
Coating system for all exterior surfaces of steel water tanks, standpipes, and tank risers	Coastal	Vinyl or urethane coating systems as listed in the painting schedule below.
Coating system for all exterior surfaces of steel water tanks, standpipes, and tank risers.	Inland	Any coating system listed in the painting schedule below.

Painting Schedule for Elevated Steel Water Tanks, Steel Standpipes, and Underground Storage Reservoirs

Surface/ Exposure	**Surface Preparation/ Pretreatment**	**Finish Type**	**1st Coat***	**2nd Coat**	**3rd Coat**
Steel tank exteriors	Commercial blast-cleaning, SSPC-SP-6	Vinyl, white or colored	SSPC Paint 9 (Four coats to obtain a minimum total dry film thickness of 5.0 mils.)		
		Vinyl, aluminum	SSPC Paint 9 (3 coats) (Minimum total dry film thickness of 5.0 mils.)	SSPC Paint 8 (1 coat)	

*Unless otherwise indicated, coatings should be applied at the spreading rate or DFT recommended by the coating manufacturer.

Surface/ Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat*	2nd Coat	3rd Coat
		High-performance urethane	MIL-P-38336 or MIL-P-26915, Type I, Class A	MIL-P-24441	MIL-C-83286 (2 coats)
			(Minimum total dry film thickness of 5.0 mils.)		
		Red lead/ alkyd	TT-P-86, Type II	TT-P-1593 or TT-E-490	TT-P-1593 or TT-E-490
Steel tank interiors	Near white blast-cleaning, SSPC-SP-10	Epoxy	MIL-P-24441 (Two or more coats as necessary to obtain a minimum total dry film thickness of 5.0 mils.)		
	Near white blast-cleaning, SSPC-SP-10. Pretreat with SSPC Paint 27.	Vinyl, white or colored	SSPC Paint 9 (Four coats with a minimum total dry film thickness of 5.0 mils.)		
		Vinyl, aluminum	SSPC Paint 9 (3 coats)	SSPC Paint 8 (1 coat)	
			(Minimum total dry film thickness of 5.0 mils.)		
Exterior of concrete tanks	(See Note A of **SOGS Section No. 09900.)**	General purpose	TT-P-19 or TT-P-55	TT-P-19 or TT-P-55	
Interior of concrete tanks	(See Note A of **SOGS Section No. 09900.)**	Epoxy	MIL-P-24441 (Two or more coats as necessary to obtain a minimum total dry film thickness of 5.0 mils.)		
		Chlorinated rubber	TT-P-95, Type I	TT-P-95, Type I	TT-P-95, Type I
		SSPC Paint 19	19	SSPC Paint 19	SSPC Paint

*Unless otherwise indicated, coatings should be applied at the spreading rate or DFT recommended by the coating manufacturer.

SOGS Section No. 15253: Water Softeners, Cation-Exchange (Sodium Cycle)

Component	*Environment - Exposure*	*Materials Selection*
Shells, pressure tanks, and mineral tanks up to 36 in. in diameter or less; brine tanks and lids.	Coastal/inland	Continuous filament wound fiberglass-reinforced pressure tanks, plastic.
Shells, pressure tanks, and mineral tanks having diameters greater than 36 in.	Coastal/inland	Steel: with a three-coat factory-applied baked phenolic-epoxy or fusion-bonded epoxy coating system on the water-side surfaces; cathodically protected on the water-side surfaces (see **SOGS Section No. 16640**); coated externally (see **SOGS Section No. 09900** for a high-performance system for exterior steel surfaces). Primer--MIL-P-26915, Type I, Class A. Intermediate--MIL-P-24441. Topcoats--MIL-C-83286 (two coats).
Brine tanks and lids; internal components for softeners	Coastal/inland	PE or FRP.
PVC--schedule 40 pipe for brine wells; schedule 80 pipe for brine tubes, air checks, and connecting pipes between brine tanks and softeners; valves and internal components of softeners	Coastal/inland	PVC.

Component	Environment - Exposure	Materials Selection
Internal components for softeners, valves, and connecting pipe tubes	Coastal/inland	Copper alloy nos. 23000, 70600, and 52100.[79]
For metering product; lines up to 2 in. in diameter	Coastal/inland	Magnetic drive disk meters with hard rubber disks and bronze housing.
For metering product; lines up to 2 to 6 in. in diameter	Coastal/inland	Magnetic drive turbo meters,[80] with the following components and materials selection: Housing: Type 316 stainless steel (on cast bronze). Rotor and nose cone: Kynar. Magnet: Ceramic. Rotor bearing, spindle, and endstone: Ceramic. Straightening vanes: Type 316 stainless steel. O-ring and tetraseal: Viton A or Buna N.

SOGS Section No. 15254: (Electrodialysis and Reverse Osmosis) Water Treatment System(s)

Component	Environment - Exposure	Material Selection
Reverse osmosis unit components: modular tube housings, center tubes, and inlet/outlet pipes to pumps; pipes for clean-in place (CIP) equipment	Coastal/inland	PVC.

[79]AWWA, *Water Quality and Treatment* (McGraw-Hill, New York, 1971), pp 369-371.
[80]*Industrial Turbo Meters*, Technical Bulletin No. Mt-4702 (Badger Meter, Inc., Milwaukee, WI, June 1980).

Component	Environment - Exposure	Materials Selection
Manifolds on modular housings	Coastal/inland	Type 317L stainless steel.
Tie-ins between modules	Coastal/inland	Polypropylene (PP).
Piping and valves	Coastal/inland	Type 317L stainless steel.
Pump materials	Coastal/inland	See **SOGS Section Nos. 15141** and **15143** for materials selection for handling seawater (or brine recycle) and product water.
Framework for plant	Coastal/inland	Continuous filament-wound fiberglass-reinforced plastic.

General Comments

Electrodialysis. Electrodialysis is not acceptable for military facilities in the Middle East because of the high operation and maintenance costs.[81] Reference to this water treatment process should be deleted from the current **SOGS Section No. 15254** until enough data are available to show that it is an acceptable, cost-effective water treatment technique.

Reverse Osmosis (RO). RO units should have a modular design that will allow an existing system to be expanded easily through the addition of modules. The RO system should include a CIP capability for membrane rejuvenation of each module (block or permeators). The CIP tank should be FRP and the associated pipes should be PVC. In addition, the required pressure should be considered in selecting materials for the associated pipes.

SOGS Section No. 15261: Chlorine-Feeding Machines (Fully Automatic, Semiautomatic, and Nonautomatic)

Component	Environment - Exposure	Materials Selection[82]
Vacuum regulator:	Coastal/inland	
Body assembly		Acrylonitrile butadiene styrene (ABS).
Flow tube		Glass.

[81] M. J. Hammer, *Water and Waste-Water Technology* (John Wiley and Sons, Inc., New York, 1975), p 264.

[82] E. J. Laubusch, "Chlorination and Other Disinfection Processes," *Water Quality and Treatment* (McGraw-Hill, New York, 1971), pp 158-224.

Component	*Environment - Exposure*	*Materials Selection*
Gaskets and O-rings		Viton.
Springs		Tantalum alloy.
Diaphragm		Chlorotrifluorethylene (CTFE).
Rate valve		Silver.
Rate valve seat and sleeve		Silver.
Inlet valve plug		Silver.
Inlet valve seat		Teflon.
Inlet filter		Silver.
Inlet assembly		Aluminum-silicon bronze/silver plate.
Vent plug		Silver.
Ejector/check valve assembly:		
Body assembly		ABS.
Diaphragm		Viton.
Diaphragm supports		CTFE.
Spring		Tantalum alloy.
Check valve assembly		ABS.
Valve seat		Viton.
Water inlet		ABS.
Solution outlet		PVC.
Miscellaneous tubing connectors		ABS.
Tubing		PE.
Water/solution gaskets		Buna N.

Component	*Environment - Exposure*	*Materials Selection*
Chlorine gas sensor	Coastal/inland	Must be able to detect 1 ppm chlorine in the atmosphere with the sensor located remote to the electronics enclosure for the detecting unit and with the detector having separate alarm and warning circuits.

General Comments

Safety. A chlorine gas sensor should be installed in the chlorination room to monitor the area continuously for escaping gas.[83] The gas detector should be a relatively maintenance-free, solid-state device that can detect at least 1 ppm by volume chlorine in the atmosphere. In addition to the safety hazard, escaping chlorine must be detected because small amounts of this gas in the atmosphere can be especially corrosive to the metals and alloys it might contact. Early detection of escaping chlorine and correction of the leak(s) would preclude this possibility.

Maintenance. Routine plumbing associated with the chlorinator(s) should be done using the guidelines in **SOGS Section No. 15401.**

SOGS Section No. 15263: Hypochlorite-Feeding Machines

Component	*Environment - Exposure*	*Materials Selection*
Pump heads, hypochlorite solution lines, and nozzles	Coastal/inland	PVC.
Check valves		Ceramic.
Diaphragms and seals/seats		Hypalon or Viton.
Diaphragm return springs		Titanium.
Hypochlorite storage tanks		PE.

[83] *Chlorine Gas Detector*, Bulletin AI.11030.6 (Capital Controls, Colmar, PA, 1977).

General Comments

Since most hypochlorite storage tanks have small capacities, they should be made of PE. Coated and lined steel tanks should not be used. The hypochlorite solution lines and nozzles should be either PVC or PE.

Routine plumbing associated with chemical metering pumps should be done using the guidelines in **SOGS Section No. 15401.**

SOGS Section No. 15302: Sewers, Sanitary Gravity Type

Environment - Exposure	*Materials Selection*
Coastal/inland - Aggressive soils	Vitrified clay pipe.[84]
Coastal/inland - Aggressive soils	Type PSM* PVC pipe that satisfies the requirements of ASTM D 3034-85b.[85]
Coastal/inland - Aggressive soils	PVC-lined concrete pipe, coated[86] externally where exposed to aggressive soils (see **SOGS Section No. 03316**).[87]
Coastal/inland - Aggressive soils	ABS pipe.[88]
Coastal/inland - Aggressive soils	FRP manholes.[89]
Coastal/inland - Aggressive soils	Concrete manholes, coated internally and coated externally where exposed to aggressive soils (see **SOGS Section No. 03316**); with cast-in-place steel-reinforced fiberglass rungs.

[84] F. S. Merritt (Ed.), pp 21-30.

*The term PSM is an arbitrary designation for a product having certain dimensions (from ASTM D 3034-856).

[85] ASTM D 3034-85b, "Specification for Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings," *ASTM Standards* (1983); *PVC Gravity Sewer Pipe for Sewer Systems*, Technical Brochure No. 40-34-24 (CertainTeed Corp., Valley Forge, PA, 1978).

[86] *Mainstay Composite Concrete Pipe*, Technical Brochure No. R2/64 (Ameron Corp., Brea, CA, 1964).

[87] *Mainstay Composite Concrete Pipe*, Technical Brochure No. ADUSS 20-3456-03 (Mainstay Corp., Roswell, GA, October 1969).

[88] R. H. Hansen, "Corrosive Waste Drainage System Design," *Heating/Piping/Air Conditioning*, Vol 55, No. 12 (December 1983), pp 71-76.

[89] *Fiberglass Flowtite Manholes*, Technical Brochure No. 5-PS-6455-A (Owens-Corning Fiberglass Corp., Toledo, OH, November 1964).

General Comments

Unlined asbestos-cement, cast-iron, ductile-iron, and concrete pipe should not be used for gravity-type sanitary sewer lines if they carry aged (decomposed) sewage containing anaerobic and aerobic bacteria that destroy the pipes' inside crowns.[90] Conditions that promote premature aging of sewage include: (1) long sewer lines, (2) warm temperatures, and (3) slow sewage flow rates.

SOGS Section No. 15303: Forced Mains, Sewer

Environment - Exposure	*Material Selection*
Coastal/inland - Aggressive soils	Cement-mortar-lined ductile iron coated externally; cathodically protected when exposed to soils with a resistivity less than 5000 ohm-cm. See **SOGS Section No. 15201.**[91]
Coastal/inland - Aggressive soils	PVC-lined steel-reinforced concrete pipe, coated externally when exposed to aggressive soils. See **SOGS Section No. 03316.**

[90] NACE, "Concrete Sewers Should Last 100 Years," *Materials Protection*, Vol 5, No. 11 (November 1966), pp 13-14.

[91] M. F. Obrecht and J. R. Myers, "Performance and Selection of Materials for Potable Hot Water Service," *Heating/Piping/Air Conditioning*, Vol 45, No. 9 (August 1973), pp 53-59.

SOGS Section No. 15304: Sewage Treatment Plant; Wet-Burning Process, Prefabricated

Painting Schedule

Surface/ Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat*	2nd Coat	3rd Coat
Steel-sewage-side surfaces of aerators, sludge settling tanks, and sludge holding systems	Near white blast-cleaning SSPC-SP-10	Coal-tar epoxy	SSPC Paint 16	SSPC Paint 16	
			(Two coats with a minimum DFT of 16 mils.)		
		Epoxy	MIL-P-24441	MIL-P-24441	MIL-P-24441
			(Three coats to an average DFT of 7.0 mils.)		
Steel--atmospheric exposure but with possible intermediate contact with sewage or chemicals	Solvent clean, commercial blast in accordance with SSPC-SP-6	High-performance	MIL-P-38336 or MIL-P-26915	MIL-P-24441 (two coats)	MIL-P-83286
Steel--all other exposures		(See **SOGS No. Section 09900**).			
Concrete in contact with sewage	(See Note A of the Painting Schedule in **SOGS Section No. 09900**)	Coal-tar epoxy	SSPC Paint 16	SSPC Paint 16	
			(Two coats with a minimum DFT of 16 mils.)		
		Epoxy	MIL-P-24441	MIL-P-24441	MIL-P-24441
			(Three coats to an average DFT of 7.0 mils.)		

*Unless otherwise indicated, coatings should be applied at the DFT recommended by the coating manufacturer.

SOGS Section No. 15401: Plumbing, General Purpose

Component	*Environment - Exposure*	*Materials Selection*
Potable water lines--temperatures 140°F or less and velocities less than 5 ft/sec	Coastal/inland - Atmospheric/soil	Type L copper water tube/fittings; copper alloy no. C 12200, ASTM B 88-83.[92]
Potable water lines--temperatures greater than 140°F and velocities greater than 5 ft/sec	Coastal/inland - Atmospheric/soil	Copper alloy no. 70600 tube/fittings.[93]
Larger diameter lines--4 in. and above	Coastal/inland - Atmospheric/soil	Cement-mortar-lined ductile iron pipe.
Valves, expansion joints, fittings, controllers, and miscellaneous components	Coastal/inland - Atmospheric/soil	Inhibited brasses/bronzes. (Compatible with ductile-cement mortar-lined pipe.) See *General Comments* below.
Pipe/valves/ fittings	Coastal/inland - Atmospheric/soil	Chlorinated polyvinyl chloride (CPVC), PVC, and polybutene (PB). Not recommended where fire codes do not permit, components can be accessed by gnawing rodents, or at locations exposed to direct ultraviolet radiation.
Hot-water heaters (less than 120 gal)	Coastal/inland	Glass-lined steel, cathodically protected on the water side (see **SOGS Section No. 16640**).
Cylindrical large-size hot-water heaters	Coastal/inland	Hydraulic cement-lined steel.[94]

[92]ASTM B 88-83, "Specification for Seamless Copper Water Tube," *ASTM Standards* (1983).

[93]Technical Manual (TM) 5-810-5, *Plumbing* (Headquarters, Department of the Army [HQDA], November 1982).

[94]J. R. Myers and M. F. Obrecht, "Corrosion Protection for Potable Water Storage Tanks: Part I--Linings," *Heating/Piping/Air Conditioning*, Vol 48, No. 12 (December 1976), pp 37-40.

Component	*Environment - Exposure*	*Materials Selection*
Cold-water storage tanks	Coastal/inland	Steel, externally and internally coated (see **SOGS Section Nos. 15240 and 15241**); coated and cathodically protected on the water side (see **SOGS Section Nos. 15240, 15241, and 16640**).[95]

General Comments

Copper Component Service Life. Industry-standard design and workmanship are demanded when copper tube systems are used. Copper tube domestic water systems can be expected to provide maintenance-free service for extended periods (up to at least 100 years) provided:[96]

1. Cut tube ends are reamed/deburred before joining.
2. Unusually aggressive fluxes (especially acid-based self-cleaning types) and excessive amounts of flux are not to be used during soldering because the acid would attack the copper.
3. No globules of solder are left on the inside tube or fitting surfaces.
4. The tubes are not dented, kinked, or bent severely during installation.
5. There are no abrupt changes in tube diameter.
6. Flared-tube fittings are installed properly.
7. The copper tube system design does not include numerous changes in the flow direction over relatively short distances.
8. The copper tube hot-water systems are not undersized (i.e., the flow rate of hot water does not exceed about 5 ft/sec routinely).
9. The circulating hot-water pumps are not oversized.
10. The temperature of the circulating hot water does not exceed 140°F routinely.
11. The water pressure does not exceed 80 psig.
12. Thermal insulations contacting the copper tubes and fittings that contain species which are aggressive to copper (e.g., chloride, ammonia, or sulfur-containing compounds) do not become wet.

[95]J. R. Myers and M. F. Obrecht, "Corrosion Control for Potable Water Storage Tanks: Part II--Cathodic Protection," *Heating/Piping/Air Conditioning*, Vol 49, No. 1 (January 1977), pp 61-66.
[96]*Copper Tube Handbook* (Copper Development Association, Greenwich, CT, 1965).

13. General guidelines in the *Copper Tube Handbook* are followed when installing copper water tube systems.

14. Galvanic and micro galvanic corrosion are avoided by not placing copper tube systems upstream of steel or galvanized steel systems.

Valves, Expansion Joints, and Other Hardware. When the domestic waters conveyed have low temporary hardness, high chloride content, and pH above 8, brasses (e.g., yellow brass, 67Cu-33Zn alloy) will dezincify as shown in Figure 3.[97] Dezincification of valve stems (the critical component with respect to corrosion in valves) can be mitigated effectively by specifying that the stems be made of a phosphorus- or arsenic-inhibited silicon red brass.[98]

Valve Seats. Valve seats in faucets should be made of Monel to prevent "wire drawing" (erosion corrosion common with conventional plated-brass seats).[99]

SOGS Section No. 15402: Plumbing, Hospital

Component	*Environment - Interior Exposure*	*Materials Selection*
Potable water system	Coastal/inland	See guidelines in **SOGS Section No. 15401.**
Distilled water system	Coastal/inland	Aluminum alloy nos. 1100, 3003. 5050, 5052, 6061, and 6063 should be used for conveying and storing distilled water (see *General Comments* below).[100]

General Comments

Distilled water at hospitals and laboratories should be conveyed by aluminum alloy systems instead of tin-lined brass.[101] Aluminum alloy tubing, piping, and valves are not affected much by distilled water, even at temperatures up to about 350°F. Furthermore, distilled water is not contaminated by contact with most aluminum alloys.[102]

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[97]W. S. Holden, *Water Treatment and Examination* (Williams & Wilkins, 1970), pp 419-434.

[98]L. P. Costas, "Field Testing of Valve Stem Brasses for Potable Water Service," *Materials Performance*, Vol 16, No. 8 (August 1977), pp 9-16.

[99]J. R. Myers, *Fundamentals and Forms of Corrosion* (Franklin, Ohio: JRM Assoc.) pp 82-84.

[100]E. H. Dix, Jr., R. H. Brown and W. W. Binger, "The Resistance of Aluminum Alloys to Corrosion, *Metals Handbook*, Vol 1 (American Society for Metals, Metals Park, OH, 1961), pp 925-926.

[101]E. H. Dix, Jr., R. H. Brown, and W. W. Binger.

[102]H. H. Uhlig (Ed.), *Corrosion Handbook* (John Wiley and Sons, Inc., New York, 1948), p 42.

It is important that the water distribution systems designed and installed are totally of aluminum alloy; they must contain no sources of heavy metal (e.g., copper and iron) ions that could be deposited on the aluminum alloy and cause pitting attack.

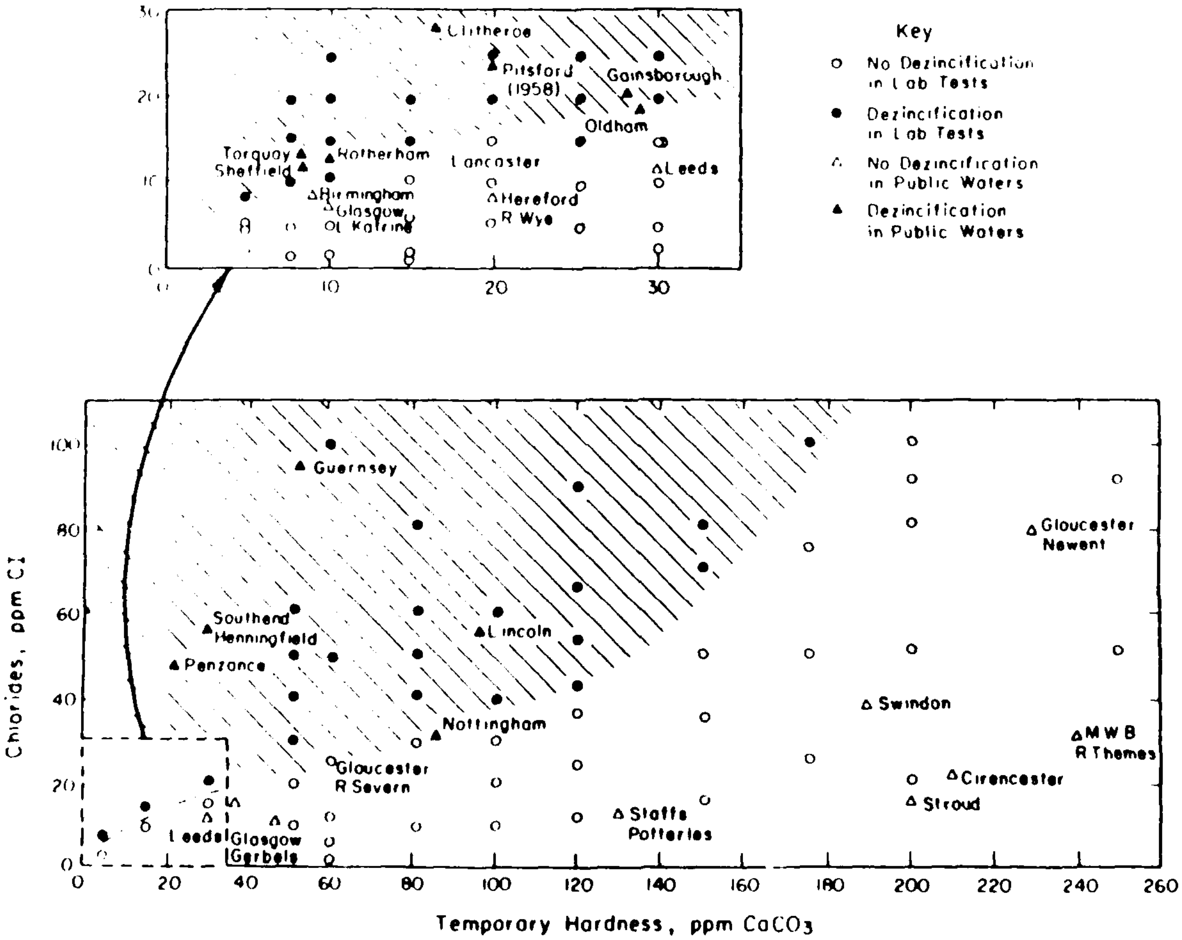

Figure 3. Effect of chloride content and temporary hardness of water on the occurrence of dezincification. (From W. S. Holden, *Water Treatment and Examination* [Williams & Wilkins, 1970]. Used with permission.)

There should be no major concern regarding exterior corrosion of the aluminum-alloy distilled-water lines unless they will be exposed to aggressive soils or wet, chloride-containing concrete. Aluminum alloys exposed to soils with resistivities less than 1500 ohm-cm should have an external coating or wrapping and cathodic protection. With regard to cathodic protection, aluminum alloys must not be overprotected; otherwise, the high pH environment created will cause "cathodic corrosion" of these amphoteric materials. In general, aluminum alloys should not be polarized to potentials more negative than about -1.2 V when referenced to a standard copper/copper sulfate electrode.

SOGS Section No. 15406: Oxygen Piping System

Component	*Environment - Exposure*	*Material Selection*
Oxygen distribution tube/fittings	Coastal/inland - Atmospheric	Type L copper water pipes which have been suitably cleaned internally (type L is specified due to the fittings which are equivalent thickness to type L). See *General Comments* below.
Color coding	Coastal/inland - Atmospheric	See **SOGS Section No. 15201** and *General Comments* below.
Underground conduit for copper oxygen lines	Coastal/inland - Underground	PVC.

General Comments

Copper Piping Handling. The Type L copper water tubing used for oxygen distribution lines should be delivered to the jobsite suitably cleaned inside for the intended application with the tube ends capped or plugged by the manufacturer. During installation, it is mandatory that no grease, oil, or other organic matter or excessive amounts of brazing flux be deposited on the inside surface. Cut tube ends must be deburred or reamed before joining. The braze alloy should have a melting temperature of at least 1000°F. After installation, the exterior surfaces of all tubes and fittings should be cleaned by washing with hot, fresh water. Guidelines in the *Copper Tube Handbook* should be followed to insure that oxygen distribution lines are installed properly.

Color Code Copper Tubing. Follow these general guidelines:

Surface Preparation	Pretreatment	Topcoats
Solvent clean as per TT-C-490, method 2.	Wash primer SSPC Paint 27 or DOD-P-15328	Appropriate alkyd enamel, depending on whether interior or exterior.

SOGS Section No. 15408: Nitrous Oxide Piping System

Component	*Environment - Exposure*	*Materials Selection*
Nitrous oxide piping system	Coastal/inland	Type L copper water tube (see *General Comments* below).
Color coding	Coastal/inland	See **SOGS Section No. 15201** and *General Comments* below.
Underground conduit for copper liner	Coastal/inland	PVC.

General Comments

Grounding. The nitrous oxide line should not be grounded to the nearest domestic cold-water pipe, because that pipe could be some distance away, leaving the bond (wire) vulnerable to damage. Furthermore, even if the domestic cold-water pipe is nearby, this grounding technique would cause galvanic corrosion if the water pipe is a ferrous-based material. The nitrous oxide line should be grounded with the proper sized copper rod and strap.

Color Code Copper Tubing. Follow these general guidelines:

Surface Preparation	Pretreatment	Topcoat
Solvent clean as per TT-C-490, method 2	Wash primer SSPC Paint 27 or DOD-P-15328	Appropriate alkyd enamel, depending on whether interior or exterior.

SOGS Section No. 15409: Vacuum Piping System

Component	*Environment - Exposure*	*Materials Selection*
Vacuum piping system	Coastal/inland	Copper tube/pipe (see **SOGS Section No. 15406**).
Color coding	Coastal/inland	See **SOGS Section No. 15406.**
Piping with diameter less than 3 in.	Coastal/inland	Type L copper water tube/ fittings.[103] See **SOGS Section No. 15406** for guidelines.

[103]*Copper Life Safety Fire Sprinkler System Handbook* (Copper Development Association, Inc., Greenwich, CT, 1973).

SOGS Section No. 15501: Sprinkler Systems, Fire Protection

Component	*Environment - Exposure*	*Materials Selection*
Large-diameter supply lines	Coastal/inland - Soil	Cement-mortar-lined ductile iron.
Fire protection tanks	Coastal/inland	Steel standpipes and water-storage tanks coated externally (see **SOGS Section Nos. 15240 and 15241**); coated and cathodically protected on the water side (see **SOGS Section Nos. 15240 and 15241**).

SOGS Section No. 15605: Fueling System for Motor Vehicles, Service-Station Type

The following requirements are considered the *minimum acceptable* to meet the Federal guidelines applicable to *all underground POL storage tanks* being installed/replaced on Army installations.*

Component	*Environment - Exposure*	*Materials Selection*
POL storage - *underground* tanks	All locations - Underground	Steel construction - Storage tanks shall be double-walled horizontal type; tank exterior shall be coal-tar- or epoxy-coated[104] and provided with a cathodic protection system or coated with a glass-fiber-reinforced polyester resin coating. Storage tanks shall be monitored by a leak detection system. See the painting schedule below for coating guidelines and **SOGS Section No. 16642** for cathodic protection guidelines. See also Leak Detection System below.

*Cathodic protection is *mandatory* for underground POL storage tanks and piping. Reference transmittal R 0214107 DEC 85 FM CDR USACE WASH DC/CEEC-EE/CEEC-EG.

[104]Naval Facilities (NAVFAC) Engineering Command Design Manual No. 22, *Petroleum Fuel Facilities* (U.S. Department of the Navy, August 1982).

Component	*Environment - Exposure*	*Materials Selection*
POL storage - underground tanks	All locations - Underground	Fiberglass-reinforced plastic. Storage tanks shall be double-walled horizontal type. Storage tanks shall be monitored by a leak detection system. See Leak Detection System below.
Anchoring system - cable, hooks, and cable clamps for underground FRP storage tanks	All locations - Underground	Steel used for the anchoring system should be galvanized; this system should be coated with coal-tar compound, MIL-C-18480, and cathodically protected using sacrificial anodes (particularly important in areas with wet or damp, aggressive soils). Steel manways should have an external coal-tar coating, MIL-C-18480, and cathodic protection with sacrificial anodes. All reinforcement steel in the concrete pads or deadmen (anchors) associated with FRP tanks should be coated with a fusion-bonded epoxy to prevent corrosion of the rebar which could cause the concrete to crack.
Distribution system piping--steel pipe and fittings	All locations - Underground/ atmospheric	Steel pipe shall be coated with continuously extruded PE. Encasement with PE sleeves is unacceptable (see **SOGS Section No. 15201**). A reasonably acceptable alternative is a hot-applied coal-tar tape system meeting AWWA C-203. Fittings and field joints should be coated with hot-applied coal-tar tape meeting AWWA C-203; or, pressure sensitive, organic-based (plastic) tapes meeting AWWA C-209 are acceptable when wrapped spirally and overlapped. Underground steel piping shall be provided with a cathodic protection system.

Component	*Environment - Exposure*	*Materials Selection*
Distribution system piping--non-metallic	All locations - Underground	Nonmetallic pipe shall be used for buried lines only.
Above-ground steel fuel storage tanks	Coastal - Atmospheric	High-performance exterior/atmospheric coating system as listed in the painting schedule below.
Above-ground steel fuel storage tanks	Inland - Atmospheric	See "atmospheric coating systems" as listed in the painting schedule below.
Concrete foundations, pads, and anchors.	All locations	See guidelines in **SOGS Section No. 03316.**

General Comments

Leak Detection System. A leak detection system shall indicate by an audible alarm and indicator lights the occurrence of a leak in any part of either tank shell. The monitoring system shall be electronic, pressure, vacuum, or liquid monitoring type. Observation wells shall be provided in areas of seasonal high groundwater where the tank is anchored in the groundwater during normal operation. The wells may use any of the leak detectors mentioned above to provide continuous monitoring. All observation wells shall be identified clearly and provided with locking devices; access will be available to the installation.

Corrosion Mitigation of Underground Steel Storage Tanks. The Steel Tank Institute (STI) recommends that steel tanks be fitted with a 0.25-in.-thick, welded-in-place steel plate (i.e., splash plate) immediately below the extended fill pipes to mitigate tank wall erosion corrosion and galvanic corrosion at this location. The 8 by 8 in. splash plates should be factory-installed and -welded to eliminate crevices at tank/splash plate interfaces. Alternatively, the fill pipes can be fitted with splash deflectors.

Dipsticks used to establish the amount of fuel in a tank should be fitted with rubber tips to insure that they will not damage the internal coatings.

Internal corrosion by water that collects inside the tank bottoms can be mitigated by installing zinc-ribbon-type anodes along the bottom interiors.

Corrosion Mitigation of Storage Tank Steel Pipes. The coated underground pipes must have cathodic protection using sacrificial anodes because anodes attached to the tanks are designed to protect only the tanks. Further, on STI-P3 tanks, the pipes are insulated from the tanks intentionally to insure that the anodes installed provide adequate cathodic protection for the tanks.

Painting Schedule: Fueling System for Motor Vehicles, Service-Station Type

Surface/ Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat*	2nd Coat	3rd Coat
Exterior steel underground fuel storage tanks	Near white metal blast-cleaning, SSPC-SP-10	Coal-tar epoxy, high-performance	SSPC Paint 16[105]	SSPC Paint 16	
			(Two or more coats as required for an average total DFT of 16 mils.)		
		Fiberglass/ resin (for maximum protection in very aggressive soils)	Factory-applied using fiberglass that meets MIL-Y-1140 and a grade of corrosion-resistant polyester resins meeting MIL-R-7575, grade B, for strength.		
		Coal-tar enamel (minimum protection)	MIL-C-18480	MIL-C-18480	
Interior steel fuel storage tanks fitted with manholes	White metal blast-cleaning, SSPC-SP-5	Epoxy	MIL-C-4556 (primer)	MIL-C-4556 (topcoat)	
			(Minimum of two coats to an average DFT of 7.5 mils.)		
		Urethane	MIL-P-23236, Type 1, Class 4	MIL-P-23236, Type 1, Class 4	
			(Two or three coats to a minimum DFT of 6 to 8 mils, depending on coating system manufacturer's recommendations.)		

*Unless otherwise indicated, coatings should be applied at the DFT recommended by the coating manufacturer.

[105]This exterior tank coating should satisfy STI requirements for STI-P3 pre-engineered steel tank according to NAVAC Engineering Command Design Manual No. 22.

Surface/ Exposure	Surface Preparation/ Pretreatment	Finish Type	1st Coat	2nd Coat	3rd Coat
Exterior above-ground steel fuel storage tanks	Commerical blast-cleaning, SSPC-SP-6 minimum; near white cleaning, SSPC-SP-10, is better	High performance urethane	MIL-P-38336 or MIL-P-26915	MIL-P-24441	MIL-C-83286 (2 coats)
	Commercial blast-cleaning, SSCP-SP-6	General-purpose	TT-P-86, Type II	TT-E-1593 or SSPC Paint 21, Type I	TT-E-1593 or SSPC Paint 21, Type I

SOGS Section Nos. 15651 and 15652:* Central Refrigeration System (for Air-Conditioning System); Refrigeration System

Component	*Environment - Exposure*	*Materials Selection*
Air-cooled condensers	Coastal - Atmospheric	Aluminum alloy tubes and fins.
Air-cooled condensers	Inland - Atmospheric	Copper fins.
Air-cooled condensers	Inland - Atmospheric	Copper tubes, aluminum alloy fins.
Ductwork and fan components	Coastal - Atmospheric (exterior air)	Aluminized steel.[106]
Ductwork and fan components	Inland - Atmospheric	Galvanized steel.
Cooling towers	Coastal/inland - Atmospheric	See **SOGS Section No. 15687.**
Plumbing		See **SOGS Section No. 15401.**

*These SOGS are combined because the corrosion control recommendations follow the same guidelines.

[106]R. J. Schmitt and J. H. Rigo, "Corrosion and Heat Resistance of Aluminum-Coated Steel," *Materials Protection*, Vol 5, No. 4 (April 1966), pp 46-52.

Component	*Environment - Exposure*	*Materials Selection*
Insulation		See **SOGS Section No. 15703.**
Painting		See **SOGS Section No. 09900.**
Water-cooled condensers		See **SOGS Section Nos. 15707 and 15708** for "closed" chilled-water systems; See **SOGS Section No. 05713** for "open-cycle" condenser water systems.

SOGS Section No. 15653: Air-Conditioning System (Unitary Type)

Component	*Environment - Exposure*	*Materials Selection*
Air-cooled condensers	Coastal - Atmospheric	Aluminum alloy tubes and fins.
Air-cooled condensers	Inland - Atmospheric	Copper fins.
Air-cooled condensers	Inland - Atmospheric	Copper tubes, aluminum alloy fins.
Cooling towers:	Coastal/inland	See **SOGS Section No. 15687.**
Field painting		See **SOGS Section No. 09900.**
Air-cooled condensers		See **SOGS Section Nos. 15651 and 15652.**
Ductwork		See **SOGS Section No. 15802.**
Fans		See **SOGS Section Nos. 15651 and 15652.**
Insulation		See **SOGS Section Nos. 15703** and **15802.**
Closed-water systems		See **SOGS Section Nos. 15802, 15707,** and **15708.**
Open-cycle water systems		See **SOGS Section No. 15713.**
Plumbing		See **SOGS Section No. 15401.**

General Comments

Aluminum fins on aluminum tubes, such as those manufactured by Carrier Corporation, should be specified for the condenser coils in window-or wall-type room air-conditioners. Units with aluminum tube/aluminum fin construction will provide long service because they do not have the galvanic corrosion associated with copper tube/aluminum fin combinations.

When installed within 1 mi from open seawater or in other corrosive environments, direct expansion coils for air-conditioner systems (other than standard window- or wall-type room units or units under 5 tons) which draw outside air across the expansion (cooling) coils shall be constructed of seamless copper tubes and copper fins bonded or soldered mechanically to the tubes. Direct expansion coils made of aluminum fins on copper tubes are acceptable for systems that pull only recirculated room air across the coils.

SOGS Section No. 15687: Ice Plant

Component	*Environment - Exposure*	*Materials Selection*
Steel brine tanks	Coastal/inland	Epoxy-coated in accordance with the guidelines in **SOGS Section Nos. 15240 and 15241**, with the brine tanks cathodically protected on the water sides.
Plumbing	Coastal/inland	See **SOGS Section No. 15401.**
Insulation	Coastal/inland	See **SOGS Section No. 15703.**
Structural and sheet-metal components	Coastal/inland	Aluminized steel.
Cooling tower	Coastal/inland	Steel-reinforced concrete with the steel reinforcements fusion-bonded epoxy coated (see **SOGS Section Nos. 15240 and 15241** and the discussion below.)

Water Quality for Ice. A basic prerequisite for producing quality ice is the availability of disinfected, clear, odorless, tasteless, iron- and manganese-free water that has a reasonably low mineral content. The water's bicarbonate hardness should be under 70 mg/L. Salt concentrations below about 170 mg/L are usually necessary for producing high-quality ice.[107] If chemically undesirable water is the only supply available, it should be treated to achieve the desired quality.

[107] E. Nordell, *Water Treatment* (Van Nostrand Reinhold, New York, 1961), p 180.

sodium hydroxide/100 lb sodium dichromate).[108] Meaningful testing should be conducted routinely to insure that approximately 1.6 g/L sodium dichromate is maintained in the brine. Sodium dichromate and caustic soda should be added as required. Alternatively, the brine can be inhibited with disodium phosphate;[109] however, sodium dichromate is reportedly more effective in mitigating external corrosion of the galvanized-steel ice cans and molds. Regardless of the inhibitor used, the brine should be treated by a qualified specialist.

Recirculating-Water Treatment (Cooling Towers) The open-cycle (recirculating) water for cooling tower systems should be treated to prevent scale formation and corrosion.[110] When properly formulated organic phosphonates are used to control scale and corrosion (i.e., nonacid treatment), the cycle of concentration (C) should not exceed that predicted by Equation 2:

$$C = \left(\frac{111{,}000}{Ca \times M}\right)^{\frac{1}{2}} \qquad \text{[Eq 2]}$$

where Ca is the calcium hardness and M is the methyl orange alkalinity, both expressed in mg/L as $CaCO_3$.[111] Corrosion and scale are prevented by controlling blowdown and maintaining an adequate concentration of properly formulated organic phosphonate in the water. The cycles of concentration permitted in the water should be adjusted downward when necessary to insure that a maximum silica content of 150 mg/L and a maximum orthophosphate concentration of about 10 mg/L are not exceeded. The cycles of concentration permitted without organic-phosphonate treatment would be based on a saturation (Langelier) index of about +0.6 at 130°F (see Appendix B). When sulfuric acid is added to mitigate scale formation, the maximum cycles of concentration allowed should be based on the solubility of calcium sulfate.[112] Open-cycle cooling tower waters should be treated with algacides and biocides, which should be slug-fed weekly. Unless the water is treated using organic phosphonates, corrosion inhibitors should be added to the open-cycle cooling water; inhibitors based on a solution that contains sodium molybdate and zinc chloride should be considered for this purpose. All open-cycle water treatment programs should be commissioned and supervised by a water treatment specialist with a proven success record in treating recirculating waters at the geographical areas where the cooling towers are located.

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[108] F. N. Speller, *Corrosion: Causes and Prevention* (McGraw-Hill, New York, 1951), pp 40-409 and 635-637.

[109] F. N. Speller.

[110] J. R. Myers, *Economic Evaluation and Cooling Tower Water Treatment Programs for Forts Wood, Rucker, Benning, Gordon, and Sill.*

[111] R. W. Lane and A. Kumar, *Selection of Cooling Water Treatments at Military Installations to Prevent Scaling and Corrosion*, Technical Report M-280/ADA087266 (USA-CERL, June 1980).

[112] *Drew Principles of Industrial Water Treatment* (Drew Chemical Corp., Boonton, NJ, 1977), p 126.

SOGS Section No 15701: Heating System: Steam, Oil-Fired

Component	*Environment - Exposure*	*Materials Selection*
Heating system, steam	Coastal/inland	See *Boiler Water Treatment* below.
Underground fuel storage tanks	Coastal/inland - Underground	Glass filament-reinforced plastic (see **SOGS Section No. 15605**).
Underground fuel storage tanks and piping	Coastal/inland - Underground	Steel tanks and piping (see **SOGS Section No. 15605**).

Boiler Water Treatment

Cost-effective corrosion and scale control for water-side surfaces of steam-heating systems can be achieved by proper treatment of the feedwater (before it enters the boiler) along with chemical additions to the boiler. In doing this, it is mandatory that essentially all condensate (i.e., 95 percent or more) be returned to the heating plant for recycling.

Initial Boiler-Fill Water. For low-pressure steam-heating systems, the initial boiler-fill water (as well as the makeup water when the system is operating) should be softened with sodium zeolite (i.e., have a hardness in the range of 0 to 1 mg/L as calcium carbonate). An effective system is to use untreated desalination plant product as the fill water. No water, however, should be introduced into the boiler until it has been established that the steam lines and condensate return lines are free of installation debris, oil and grease, and other foreign matter. If the water used for the boiler makeup contains a bicarbonate alkalinity such that heating the water will produce 5 ppm carbon dioxide gas, consideration should be given to installing a dealkalizer. The dealkalizer should be of a size that can remove at least 90 percent of the methyl orange (M) alkalinity from the makeup water. Equally important is that the deaerator is vented properly.

Boiler-Water Treatment for Pressures up to 200 psig Boiler waters must be treated chemically to control both scale and corrosion. A well established procedure for this treatment involves adding certain polyphosphates (e.g., sodium tripolyphosphate for low-hardness waters), sodium sulfite, sodium hydroxide, and tannin to the boiler water. The following limits should be maintained:[113]

1. Total dissolved solids (TDS) less than 3500 mg/L. The desired TDS content of the boiler water can be achieved through proper blowdown control.
2. Phosphate (as PO_4)--30 to 60 mg/L.
3. Sodium sulfite (as Na_2SO_3)--20 to 40 mg/L.
4. Hydroxide (as OH^-)--80 mg/L.
5. Enough tannin to present a "tea" color.[114]

[113]J. W. McCoy, *The Chemical Treatment of Boiler Water* (Chemical Publishing, New York, 1981), p 34.

[114]L. Goldman, *Boiler-Water Treatment Manual for Federal Plant Operators* (U.S. Department of the Interior, Bureau of Mines, 1951).

In general, the sodium sulfite (an oxygen scavenger) and caustic soda (for alkalinity control) are fed continuously (as required) at the condensate tank or the storage section of the deaerator. Polyphosphates (for scale control) can be fed intermittently at the same location or can be slug-fed to the boiler water.

Chemical Treatment of Feedwater. If the feedwater (i.e., the makeup water plus the returned condensate) may release carbon dioxide in the boiler, a neutralizing amine should be added to mitigate general corrosion (carbon dioxide grooving) of the steel condensate return lines.

For condensate treatment where required, use cyclohexylamine for long-line systems or morpholine for short-line systems; a pH of 7.4 to 7.8 is required for the condensate.

Monitoring. Effective water-side corrosion and scale controls for a steam-heating system require periodic chemical analysis of the boiler water, steam, condensate (at selected locations throughout the system), makeup water, and feedwater. Table 1 summarizes tests for these products. The tests should be conducted at least every 8 hr under the limits prescribed for each. The tests must be done only by trained personnel. In addition, a representative of the organization furnishing the treatment chemicals should visit the heating plant at least every 2 months to conduct the tests identified in Table 1 and compare his or her data with those of the onsite water analyst. Any discrepancies between the two sets of data should be resolved immediately.

Boiler Storage. Boilers should be stored according to the manufacturer's recommended procedure for wet lay-up for 30 days and less, and dry lay-up for times longer than 30 days.

SOGS Section Nos. 15702, 15705, 15711, and 15712:* Heating System: Forced-Hot-Water, Oil-Fired; Heating System: Forced-Hot-Water, High-Temperature Water Converter and Steam Converter; Hot-Water Plant and Heating Distribution System; and Hot-Water Heating System Wet Fill and Cap

Component	*Environment - Exposure*	*Materials Selection*
Heating system--forced hot-water, oil-fired	Coastal/inland	See discussion below.
Expansion tanks	Coastal/inland	Nitrogen-blanketed.
Insulation	Coastal/inland	See **SOGS Section No. 15703.**
Tubes for steam-converter-type heat exchangers	Coastal/inland	Copper alloy no. 70600.

*These SOGS are combined because the corrosion control recommendations for "closed" hot-water heating systems follow the same guidelines.

Component	*Environment - Exposure*	*Materials Selection*
Underground fuel storage tanks	Coastal/inland	Glass-filament-reinforced polyester. See **SOGS Section No. 15605.**
Underground fuel storage tanks and piping	Coastal/inland	Steel tanks and piping. See **SOGS Section No. 15605.**

Table 1

Tests and Chemical Control Limits for Maintaining a Properly Treated Low-Pressure Steam-Heating System

Test Site (minimum for daily control)

S-1: Boiler water. Could be taken from continuous blowdown or from the water column.
S-2: Steam. Freshly condensed steam directly out of the boiler.
S-3: Condensate. Immediately after processes. Probably will include more than one test site.
S-4: Makeup water.
S-5: Feedwater. Collect sample after feedwater pump (i.e., just before boiler). Remember that raw water could leak into the feedwater if water-sealed pumps are used. However, water-sealed pumps are usually only used for 500 gal and larger boilers.

Boiler (S-1)	**Boiler (S-2)**	**Condensate (S-3)**	**Makeup (S-4)**	**Feedwater (S-5)**
1. PO_4 = 30 to 60 ppm[a] 2. Na_2SO_3 = 20 to 40 ppm 3. TDS ≤3500 ppm 4. 2P-M = OH 80 ppm as OH or 250 ppm as $CaCO_3$ 5. Organic tannin = "tea"	1. pH_{min} = 7.4 to 7.8 2. CO_2 = trace to 2 ppm 3. Spec. Cond. ≤100 mhos or have carryover	1. *Hardness <0* or have leak 2. Spec. Cond. ≤100 mhos (should be same as team)	1. Hardness <0 to 1 ppm if water is softened[g] 2. M Alk = 10% of M_{raw} if dealkyzed 3. Cl^- should be a constant value	1. Hardness <1 ppm if softened

Tests

1. Spec. Cond.	1. Spec. Cond.	1. Spec. Cond.	1. Spec. Cond.	1. Spec. Cond.
2. P&M Alk.	2. CO_2	2. Hardness	2. Hardness	2. Hardness
3. Na_2SO_3	3. M Alk[c]	3. M Alk	3. M Alk[h]	3. M Alk
4. PO_4	4. Cl^-[d]	4. Cl	4. Cl	4. Cl
5. Cl^-[b]	5. pH	5. CO_2		
6. Color		6. pH[e,f]		

[a]The better the control, the lower the $PO_4^=$ concentration can be in the boiler.
[b]Cl^- *of the boiler will depend on the water used.*
[c]M Alk of condensate steam sample may be high from amines, but should be a stable figure.
[d]Cl^- in steam sample says "carryover."
[e]pH of condensed steam sample is measured for amine control.
[f]CO_2 and pH of condensate are measured for amine distribution.
[g]On specific condition of condensed steam sample, 1/2 of 1 percent of the boiler water spec. cond. is acceptable as carryover (about 35 mhos) and the spec. cond. contribution of CO_2 and the amines about 50 mhos; thus, the total < *100* mhos.
[h]If SiO_2 content is high in makeup water, keep OH^- in boiler water > 100 ppm as OH^-.

Corrosion and Scale Control for Forced-Hot-Water Heating Systems:

Hot-water heating systems generally are categorized according to the temperature 12d pressure of the water conveyed. High-temperature hot-water (HTHW) heating systems operate above 350°F and 450 psi; medium-temperature hot-water (MTHW) heating systems operate at 250 to 350°F with pressures above 30 psi; and low-temperature hot-water (LTHW) heating systems operate below 250°F at a maximum pressure of 30 psi.[115]

1. Initial fill and makeup water for closed systems: distilled or demineralized.

2. LTHW (see **SOGS Section Nos. 15707 and 15708**):

   - Corrosion control for closed low-temperature hot-water systems: maintain 3000 to 4000 mg/L sodium nitrate in the water and a pH of 8 to 8.5 in conjunction with a copper-alloy corrosion inhibitor such as BT or MBT for temperatures over 180°F; 1500 to 2000 mg/L sodium nitrite for temperatures under 180°F.[116] Or, maintain 100 mg/L sodium chromate in the water for temperatures less than 180°F; at least 2000 mg/L sodium chromate for temperatures above 180°F.[117]

   - Scale and deposit control for closed low-temperature hot-water systems: sodium polyacrylates, polymethacrylates, polymaleates, sulfonated polystyrene, carboxymethyl-cellulose, lignins, or phosphonates.

3. MTHW:

   - Corrosion control for closed medium-temperature hot-water systems: maintain 20 mg/L sodium sulfite in the water and pH in the 9 to 10 range using sodium hydroxide.[118]

   - Scale and deposit control for closed medium-temperature hot-water systems: polyacrylates, polymethacrylates, and phosphonates.

4. HTHW:

   - Corrosion control for closed high-temperature hot-water systems: maintain 20 mg/L sodium sulfite in the water and a pH in the 9 to 9.5 range using sodium hydroxide.

   - Scale and deposit control for closed high-temperature hot-water systems: chemicals must be stable at the operating temperatures.

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[115] R. T. Blake, *Water Treatment for HVAC and Potable Water Systems* (McGraw-Hill, New York, 1980), pp 143-153.
[116] R. T. Blake.
[117] R. T. Blake.
[118] R. T. Blake.

5. Closed system testing: The initial chemical dosage (I) for a closed hot-water heating system should be estimated using Equation 3:[119]

$$I = (P/120)\,(V/1000) \qquad \text{[Eq 3]}$$

where P is the desired dosage in milligrams per liter, V is the total system volume in gallons, 120 and 1000 are conversion factors, and I is measured in pounds.

Adequate testing is required to insure that the proper inhibitor concentrations are maintained in closed hot-water heating systems. "Adequate" means initially and at least every 8 hr immediately after upset conditions, or weekly for systems with low makeup rates. Chemicals must be added to closed hot-water heating systems in accordance with the results of these analyses. Only trained analysts should conduct these tests. When the amount of makeup water added to a closed system is known (e.g., through metering), the amount of inhibitor needed (F) can be reasonably estimated using Equation 4:

$$F = (P/120)\,(M/1000) \qquad \text{[Eq 4]}$$

where P is the desired dosage in milligrams per liter, M is the makeup water in gallons, and F is measured in pounds.

All testing must be conducted using accepted analytical methods. The onsite analyst's test data should be compared at least every month with those obtained by a representative of the organization furnishing the treatment chemicals. Any discrepancies between the two data sets should be resolved immediately. Chemicals should not be purchased from an organization that does not provide this service.

Regardless of the chemical(s) used, closed hot-water heating systems must be kept very clean. Sidestream filters often are used to achieve this objective.

SOGS Section No. 15703: Heat-Distribution Systems Outside Buildings

Component	*Environment - Exposure*	*Materials Selection*
Casings	Coastal/inland - Underground/ atmospheric	Steel with factory-applied external coatings, field-coated/wrapped at welds and cathodically protected where exposed to soils with resistivities less than 5000 ohm-cm.[120] See **SOGS Section No. 16642.**

[119] *Drew Principles of Industrial Water Treatment*, pp 147-151.

[120] J. Larson-Badse and F. Brockett, "Performance of Galvanized and Aluminum Coated Wire Strand in Marine Atmospheres," *Materials Performance*, Vol 9, No. 12 (December 1970), pp 21-24.

Component	*Environment - Exposure*	*Materials Selection*
Casings	Coastal/inland - Underground/ atmospheric	Ductile iron with factory-applied external coatings, field-coated/wrapped at welds and cathodically protected where exposed to soils having resistivities less than 5000 ohm-cm. See **SOGS Section No. 16642.**
Above-ground jackets	Coastal/inland - Atmospheric	Aluminum alloys, electrically insulated from the steel pipes.
Casing insulation	Coastal/inland	Must contain no leachable corrosive species such as halides and no heavy-metal ions where jacketed with aluminum alloys; it must be proven that the insulation is dry just prior to sealing the system. (See note on Installation of Heat Distribution systems.)
Manholes	Coastal/inland	Concrete, coated where exposed to aggressive soils (see **SOGS Section No. 03316**). Steel-reinforced fiberglass should be used as cast-in-place rungs for concrete manholes.
Manholes	Coastal/inland	Glass-filament-reinforced plastic.

Casing Insulation

Insulation inside the casings should contain few, if any, leachable aggressive ions such as chloride.[121] Heavy metal (e.g., copper and iron) ion-containing insulation should also be excluded when an aluminum jacket must be insulated electrically from the heat-distribution pipes. In addition, the aluminum alloy used for the thin (0.016-in.-thick) above-ground jackets should have proven corrosion resistance in humid, dusty, salt-laden, coastal environments or where the atmosphere can be contaminated with industrial pollutants.

[121] J. F. Delahunt, "Corrosion Control Under Thermal Insulation and Fire Proofing," *Bulletin of the Institution of Corrosion Science and Technology*, Vol 20, No. 2 (May 1982), pp 2-7.

FRP Pipes

Foamed polyurethane-insulated FRP condensate or hot-water pipes should not be used if there is any possibility they will be exposed to thermal environments exceeding about 250°F. Temperatures in excess of 250°F, even for short periods of time, could cause dimensional instability and eventual failure of the material.

Installation of Heat-Distribution Systems

Immediately after installation of the heat-distribution system (but before the system's underground section is covered with soil or sand), warm air should be forced through the insulation-containing annulus from one end of the system until no condensation appears on an ambient-temperature mirror (shaded from the sun) located at the other end. This procedure will insure that the insulation is dry. Concurrently, it is desirable to force a gas such as helium through the insulation zone to locate (using a suitable leak detector) and repair any leaks in the casings. It cannot be overemphasized that the insulation must remain dry.

SOGS Section Nos. 15707 and 15708:* Chilled-Water Distribution System Wet Fill and Cap; Chilled-Water Plant and Distribution System

Component	*Environment - Exposure*	*Materials Selection*
Chilled water distribution system	Coastal/inland	See *Corrosion Control for Closed Chilled-Water Systems* below.

Corrosion Control for Closed Chilled-Water Systems

The metallic pipes and other water-side equipment in closed water systems theoretically should not corrode after the dissolved oxygen introduced with the initial fill is consumed by corrosion. However, truly closed chilled-water systems almost never exist.[122] Makeup water containing dissolved oxygen is added routinely to nearly all closed systems. Therefore, closed chilled-water systems must be treated chemically to control corrosion.[123] The following measures should be taken:

1. Initial fill and makeup water for closed systems: distilled or demineralized.

2. Chemical treatment of water: sodium nitrite-borax inhibitor containing an inhibitor for copper/copper alloys (e.g., BT or MBT); maintain 1400 mg/L sodium nitrite in the water and a pH of 8 to 9.[124]

3. Alternative chemical treatment of water: maintain 500 mg/L (minimum) sodium chromate in the water, with a pH of 7 to 9 achieved using sodium hydroxide.

*These SOGS are combined because the corrosion control recommendations follow the same guidelines.

[122] S. Sussman, "Is Your Closed Circulating Water System Really Closed?" *Heating, Piping, and Air Conditioning* (April 1965).

[123] S. Sussman and J. B. Fullman, "Corrosion in Closed Circulating Water Systems," *Heating and Ventilating* (October 1953).

[124] R. T. Blake.

4. Water analysis: the specific conductance of the nitrite-borax-inhibited chilled water should be measured every 8 hr after the water is first treated. Concurrently, the water's sodium nitrite content should be measured. Typically, an adequate concentration of inhibitor (i.e., about 1400 mg/L sodium nitrite) is reached when the untreated water's specific conductance is increased by about 2700 micro-mhos. Once the system has stabilized with regard to these analyses, the test interval can be increased to 24 hr and, eventually, to 1 week. If an upset occurs in the system (e.g., an unusual amount of makeup water is added or there is a major loss of conductance and/or nitrite), it will be necessary to return to the original 8-hr (or even more frequent) analysis program.

SOGS Section No. 15713: Open-Cycle Condenser Water System

Component	*Environment - Exposure*	*Materials Selection*
Condenser tubes	Coastal/inland	Commercial purity titanium or Ti-Code-12 titanium alloys: for condenser tubes which will convey sulfide or ammonia-containing polluted waters or where velocities will exceed 7 ft/sec.[125]
Condenser tubes	Coastal/inland	Copper alloy no. 70600 for condenser tubes that will not convey sulfide or ammonia-containing polluted waters or where the flow rate does not exceed 7 ft/sec.
Tubesheet for condensers	Coastal/inland	Copper alloy no. 70600-clad steel.
Water boxes for condensers	Coastal/inland	Steel, with water-side surfaces coated and cathodically protected (see **SOGS Section Nos. 15240, 15241, and 16641**).
Larger diameter underground pipes for conveying cooling water	Coastal/inland	Cement-mortar lined ductile iron pipes, coated externally and cathodically protected where exposed to soils with resistivities less than 5000 ohm-cm.[126]

[125] D. F. Hasson and C. R. Crowe, "Titanium for Offshore Oil Drilling," *Journal of Metals*, Vol 34, No. 1 (The Metallurgical Society of AIME, Warrendale, PA, January 1982), pp 23-28; *Drew Principles of Industrial Water Treatment*, p 144.

[126] J. R. Myers and M. A. Aimone, *Corrosion Control for Underground Steel Pipelines: A Treatise on Cathodic Protection* (JRM Associates, Franklin, OH. 1977), p 25.

Component	*Environment - Exposure*	*Materials Selection*
Underground pipes for conveying cooling water	Coastal/inland - Underground	Continuous filament-wound glass-reinforced plastic pipe.[127]
Underground pipes for conveying cooling water	Coastal/inland - Underground	Vinyl-lined concrete pipe, coated externally where exposed to aggressive soil (see **SOGS Section No. 03316**).[128]

Materials

Figure 2 in **SOGS Section Nos. 15141 and 15143** gives general guidelines for selecting metallic materials for seawater service (including power-plant and naval condensers).[129] In reviewing Figure 2, it should be noted that certain materials (e.g., austenitic stainless steels) pit and/or foul (causing concentration-cell corrosion) at low seawater velocities. Other materials undergo erosion corrosion when the velocity exceeds critical values.

Chemical Treatment of Cooling Water

Chemical treatment should not be necessary for a once-through cooling water unless suboptimal materials were used in making the condenser. Water treatment should not be implemented unless fouling, scale formation, and/or corrosion become problems. Any water treatment program found necessary should be designed, implemented, and monitored by a qualified specialist who has a proven success record in treating open-cycle, once-through, cooling water systems.

SOGS Section No. 15801: Ventilating System, Mechanical

Component	*Environment - Exposure*	*Materials Selection*
Ductwork and sheet metal components	Coastal - Atmospheric	Aluminized steel.[130]
Ductwork and sheet metal components	Inland - Atmospheric	Galvanized steel.
Hoods over cooking equipment	Coastal/inland - Atmospheric	Type 304 stainless steel.

[127] J. R. Meyers and M. A. Aimone.
[128] J. R. Myers and M. A. Aimone.
[129] D. F. Hasson and C. R. Crowe.
[130] R. J. Schmitt and J. H. Rigo, "Corrosion and Heat Resistance of Aluminum-Coated Steel"; J. Larsen-Badse and F. Brockett, "Performance of Galvanized and Aluminum Coated Wire Strand in Marine Atmospheres"; L. L. Shreir (Ed.), *Corrosion*. Ch 14, pp 17-30.

Component	*Environment - Exposure*	*Materials Selection*
Insect screen (including the framework)	Coastal/inland - Atmospheric	Type 304 stainless steel.
Painting	Coastal/inland -	See **SOGS Section No. 09900.**

SOGS Section No. 15802: Air-Supply and Distribution System (for Air-Conditioning)

Component	*Environment - Exposure*	*Materials Selection*
For ductwork and sheetmetal components	Coastal - Atmospheric	Aluminized steel.
For ductwork and sheetmetal components	Inland - Atmospheric	Galvanized steel.
Water tube--underground service	Coastal/inland - Underground	Type K copper water tube cathodically protected where exposed to corrosive soils.
Insulation for pipes and ducts	Coastal/inland	See guidelines presented in **SOGS Section No. 15703**; must have an effective vapor barrier over the insulation.[131]
U-bend tubes for heat exchangers where water temperatures will exceed 140°F and/or water velocities will exceed 5 ft/sec	Coastal/inland	Copper alloy no. 70600.
U-bend tubes for heat exchangers where water temperatures will be less than 140°F and/or water velocities will not exceed 5 ft/sec	Coastal/inland	Copper alloy no. 12200.

[131] J. F. Delahunt.

Component	*Environment - Exposure*	*Materials Selection*
Paint	Coastal/inland	See **SOGS Section No. 09900.**
Closed-system water treatment	Coastal/inland	See **SOGS Section Nos. 15707 and 15708.**
Cooling-coil fabrication for air cooled condensers	Coastal/inland	See **SOGS Section Nos. 15651 and 15652.**

SOGS Section No. 15812: Warm-Air Heating System

Component	*Environment - Exposure*	*Materials Selection*
Vent/flue connections and associated hardware	Coastal/inland	Aluminized steel.
Vent connection to building exhaust	Coastal/inland	Equal to the size of the heater flue.
Flue-gas temperature	Coastal/inland	Not less than 212°F before exiting the vent pipe.[132]

[132] F. S. Merritt (Ed.), Ch 19, p 23.

13 ELECTRICAL

SOGS Section Nos. 16113 and 16115: Underfloor Duct System; Underfloor Raceway System (Cellular Floor)

Component	*Environment - Exposure*	*Materials Selection*
Sheet metal components for underfloor electrical distribution system	Coastal/inland	Hot-dipped galvanized steel.

General Comments

All sheet-metal components (e.g., the cellular floor panels) for the underfloor electrical distribution systems in buildings should be made of hot-dip-applied galvanized steel. Shrinkage reinforcements consisting of welded-wire fabric in the associated concrete should also be hot-dipped galvanized type. Equally important is that all concrete which might be cast in place against the galvanized steel sheet metal contain a minimum number of chloride ions (see **SOGS Section No. 03316**).

SOGS Section Nos. 16210, 16211, 16212, and 16213:* Generating Units; Diesel-Electric; 10-kW to 6.0-MW; With Auxiliaries

Component	*Environment - Exposure*	*Materials Selection*
Underground steel diesel-fuel storage tanks	All locations	See **SOGS Section No. 15605.**
Underground FRP tanks for diesel-fuel storage	All locations	FRP storage tanks shall be double-walled horizontal type. Storage tanks shall be monitored by a leak detection system. (See **SOGS Section No. 15605.**)
Coatings for exterior surfaces of diesel-engine exhaust stacks	All locations	See guidelines on high-temperature coatings in **SOGS Section No. 09900** and Figure 4. MIL-P-14105 (up to 1400°F service), MIL-P-26915 (up to 750°F), or MIL-P-38336 (up to 750°F) is recommended for coastal or highly corrosive environments.

*These SOGS are combined since the corrosion control recommendations for diesel-electric generating systems are essentially identical, regardless of unit capacity.

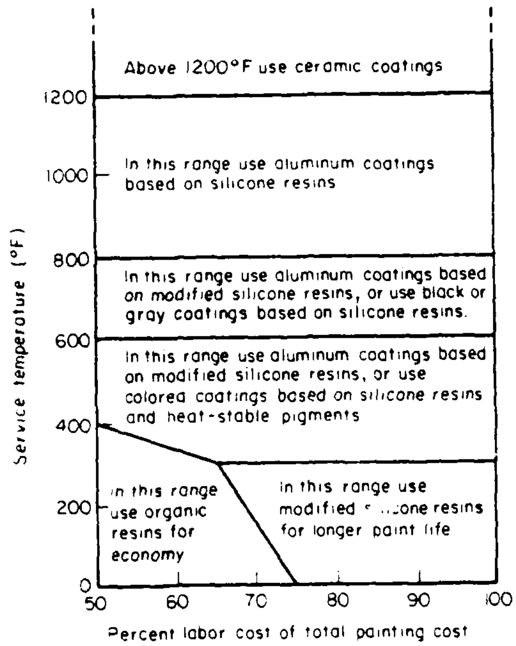

Figure 4. Specifier's guide to selection of silicone coatings. (From G. E. Weismantel, *Paint Handbook* [McGraw-Hill, New York, 1981]. Used with permission.)

Cooling System: Water

The operations and maintenance instruction manuals supplied with the diesel engine generating system shall include manufacturer's recommendations for makeup water quality and water treatments necessary to mitigate (1) general corrosion in the diesel engine cooling system and (2) cavity corrosion of the cylinder liners. Under no circumstances shall untreated water be used in the cooling system.

Cooling Sytem: Towers

When cooling towers are used instead of radiators to remove heat from the closed system water, the chemistry of the open-side recirculating water must be controlled to prevent excessive scale formation and/or corrosion. Scale can be mitigated by controlling the concentration cycles, acid feeding, and/or chemical treatment.[133] Corrosion caused by open-side recirculating water often must be treated with algacides and biocides. A specialist should establish the water treatment program when open recirculating waters are involved.

Expansion tanks

Expansion tanks should be nitrogen-blanketed to exclude moisture.

[133] J. R. Myers.

SOGS Section No. 16402: Electrical Work, Interior

Component	*Environment - Exposure*	*Materials Selection*
Underground conduits	Coastal/inland - Underground	Steel/galvanized steel, coated and cathodically protected where exposed to soils having resistivities less than 10,000 ohm-cm. See **SOGS Section No. 16642.**
Ground rods	Coastal/inland - Underground	Hardened copper, cathodically protected where exposed to corrosive soils.

General Comments

Aluminum-to-copper electrical contact should be avoided, especially in highly humid areas. This contact would cause galvanic corrosion of the aluminum, producing an aluminum oxide insulator and undesirable high-resistance contacts.

SOGS Section No. 16530: Protective Lighting Systems

Component	*Environment - Exposure*	*Materials Selection*
Poles, standards and associated hardware	Coastal/inland - Atmospheric	Aluminized steel.
Poles, standards	Coastal/inland - Atmospheric	Aluminum alloys.

General Comments

Aluminum alloy no. 2024-T4 should not be used for hardware on protective lighting systems because this material is susceptible to stress-corrosion cracking.[134] In addition, the 1.0-in.-diameter, 40-in.-long anchor bolts for standard aluminum pole systems should not be galvanized steel because galvanic corrosion will occur.[135] When possible, anchor bolts and hardware should be made of aluminized steel. Cadmium-coated steel is a reasonable substitute if aluminum-coated components are not readily available.

Aluminized steel could be used for the entire protective lighting system (i.e., the standards, shafts, bracket arms, anchor bolts, and other hardware.[136] Aluminized steel's satisfactory performance for many years in a wide variety of atmospheric environments is well documented. Aluminized steel can be painted if additional protection is required.[137]

[134]B. R. Brown (Ed.), *Stress-Corrosion Cracking in High-Strength Steels and in Titanium and Aluminum Alloys* (U.S. Naval Research Laboratory, Washington, D.C., 1971), pp 176-191.

[135]J. Larsen-Badse and F. Brockett, "Performance of Galvanized and Aluminum Coated Wire Strand in Marine Atmosphere," *Materials Performance*, Vol 9, No. 12 (December 1970), pp 21-24.

[136]J. Larsen-Badse and F. Brockett.

SOGS Section No. 16532: Electrical Distribution and Street-Lighting System

Component	*Environment - Exposure*	*Materials Selection*
Poles and hardware	Coastal - Atmospheric	Aluminized steel.
Poles and hardware	Inland - Atmospheric	Galvanized steel.
Guy rods, wire rope and associated hardware	Coastal - Atmospheric/ underground	Aluminized steel with rods cathodically protected where exposed to soils having resistivities less than 10,000 ohm-cm.[138]
Wire rope	Coastal - Atmospheric	Austenitic stainless steel (eg. type 304 stainless steel).
Pads, vaults, ducts, and manholes	Coastal/inland	Concrete. See guidelines presented in **SOGS Section No. 03316.**
Guy rod-wire rope connections	Coastal/inland	Porcelain insulators.[139]
Direct-buried cable	Coastal/inland - Underground	PE jacketed cable.
Painting and manholes	Coastal/inland	See guidelines in **SOGS Section No. 09900.**

Paper-Insulated Lead Sheath Cable

Not recommended for direct burial or concrete duct installations.

Stainless Steel

Not recommended for transformer cases where the vaults can be flooded with sea or brackish waters.

Steel

Transformer cases in vaults; coated and cathodically protected using sacrificial anodes where vaults can be flooded.

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[137] L. L. Shreir (Ed.), *Corrosion*, Vol 2 (Newnes-Butterworths, London, 1976), pp 14:25-14:28.

[138] *Manual on Underground Corrosion in Rural Electric Systems*, Bulletin 161-23 (U.S. Department of Agriculture [USDA], Rural Electrification Administration, October 1977); R. A. Gummow, "Power System Corrosion," Report No. 091 D 188 (Canadian Electrical Association, Montreal, August 1983); O. W. Zastrow, "Copper Corrosion in Moderate and High Resistivity Soils," *Materials Performance*, Vol 13, No. 8 (August 1974), pp 31-36.

[139] R. A. Gummow.

SOGS Section No. 16610: Lightning Protection System

Component	*Environment - Exposure*	*Materials Selection*
Ground rods, straps, and wire	Coastal/inland - Underground/atmospheric	Solid copper, cathodically protected using sacrificial anodes where exposed to corrosive soils.
Dissimilar metal/ alloy connections	Coastal/inland - Underground/atmospheric	Coated with a bitumastic (asphalt base for above-ground and coal-tar base for underground) or silicone rubber sealant.

General Comments

Only copper rods and straps should be used for grounding systems in the Middle East. Ground rod-to-soil potential should be surveyed annually to determine where, if any, active corrosion of underground copper is occurring. This survey is in addition to the routine ground-resistance measurements taken to insure proper grounding of the lightning protection system. Table 2 lists the correlations between copper tube-to-soil potential and the underground corrosion activity of copper for most soils.[140]

Aluminum and its alloys should be avoided for grounding applications because they are anodic to commonly used metallic materials; when connected to a more noble metal, rapid localized aluminum corrosion will occur in coastal environments. Applying a bitumen-type coating to these connections would help mitigate this galvanic corrosion. Another important point is that aluminum wire has a tendency to oxidize and, when stressed, it creeps. These phenomena can result in undesirable high-resistance bonds and connections.

SOGS Section 16640: Cathodic Protection System (Sacrificial Anode)*

The Need for Cathodic Protection

Cathodic protection is mandatory for underground POL storage tanks and piping. The cathodic protection system must be designed and installed by an experienced, qualified contractor who specializes in corrosion mitigation methods.

Determining Type and Design of Cathodic Protection System

If the soil resistivity is low (less than 5000 ohm-cm) and the current density requirement is low (less than 1 mA/sq ft), a sacrificial anode (galvanic) system can be used. Figure 5 gives general guidance for selecting a sacrificial anode or an impressed-current-type anode.

[140]*Manual on Underground Corrosion in Rural Electric Systems.*

*Except where otherwise noted, all requirements shall conform to CEGS 16640 and SOGS 16640.

Table 2

Copper Tube-to-Soil Potential Compared With Underground Corrosion Activity for Most Soils

Potential, Volt Vs. Cu - $CuSO_4$ Half Cell	Corrosion Activity
-0.5 or more negative	Copper is well protected; suggest that the copper is cathodically protected
-0.25 or more negative	No corrosion in most soils
-0.1 or less negative	May be corroding
0.0 or positive	Probably corroding

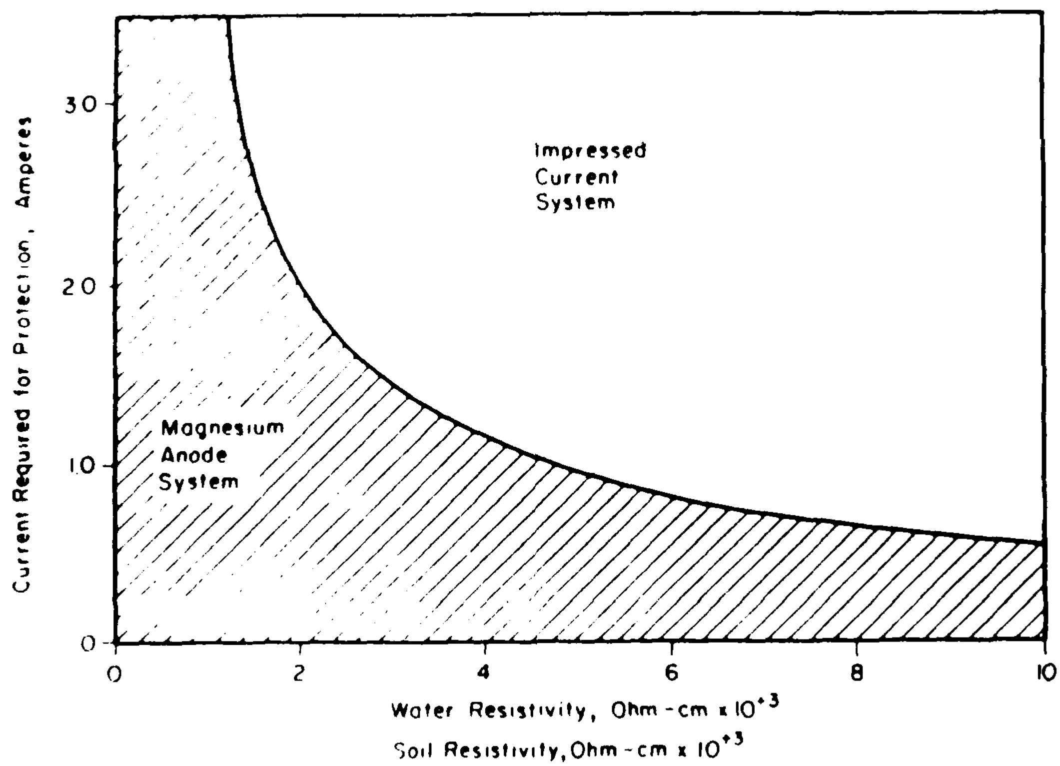

Figure 5. General guide for selecting a magnesium-alloy sacrificial anode or an impressed-current-type cathodic protection system. (From W. Von Baeckmann and W. Schwenk, *Handbook of Cathodic Protection* [Portcullis Press, Ltd., London, 1971]. Used with permission.)

General Requirements

Services of a Corrosion Engineer. The contractor should hire a qualified corrosion engineer to supervise and inspect the installation of the cathodic protection system. This person may be a licensed professional engineer or certified as being qualified by NACE if the licensing or certification has required suitable experience in corrosion control on buried or submerged metallic piping systems and metallic tanks.

Cathodic Protection System Design. The design of a cathodic protection system (sacrificial anode) should be based on the guidance in TM 5-811-7.[141] Figure 6 shows the design sequence for a cathodic protection system (sacrificial anode). Before the system is designed, the following preliminary data must be gathered:[142]

- Physical dimensions of structure to be protected.
- Drawing of structure to be protected.
- Electrical isolation.
- Short circuits.
- Corrosion history of structures in the area.
- Electrolyte resistivity (a structure's tendency to corrode is proportional to the electrolyte resistivity, which is a measure for determining corrosivity).
- Electrolyte pH.
- Structure versus electrolyte potential (for existing structures, the potential between the structure and the electrolyte will give a direct indication of the corrosivity for determining anodic and cathodic sites and provide data for determining criteria of protection).
- Current requirement. A critical part of design calculations for cathodic protection systems on existing structures is the amount of current required per square foot (called "current density") to change the structure's potential to achieve design criteria. The current density required to shift the potential indicates the structure's surface condition. A well coated structure (for example, a pipeline well coated with coal-tar epoxy) will require a very low current density (about 0.05 mA/sq ft); an uncoated structure would require a high current density (about 10 mA/sq ft). The average current density required for cathodic protection is 2 mA/sq ft of *bare* area. Table 3 gives typical current density requirements for cathodic protection of uncoated steel.
- Coating resistance. A coating's resistance decreases greatly with age and directly affects structure-to-electrolyte resistance for design calculations.

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[141]TM 5-811-7, *Electrical Design, Cathodic Protection* (HQDA, 1985).
[142]J. R. Myers and M. A. Aimone.

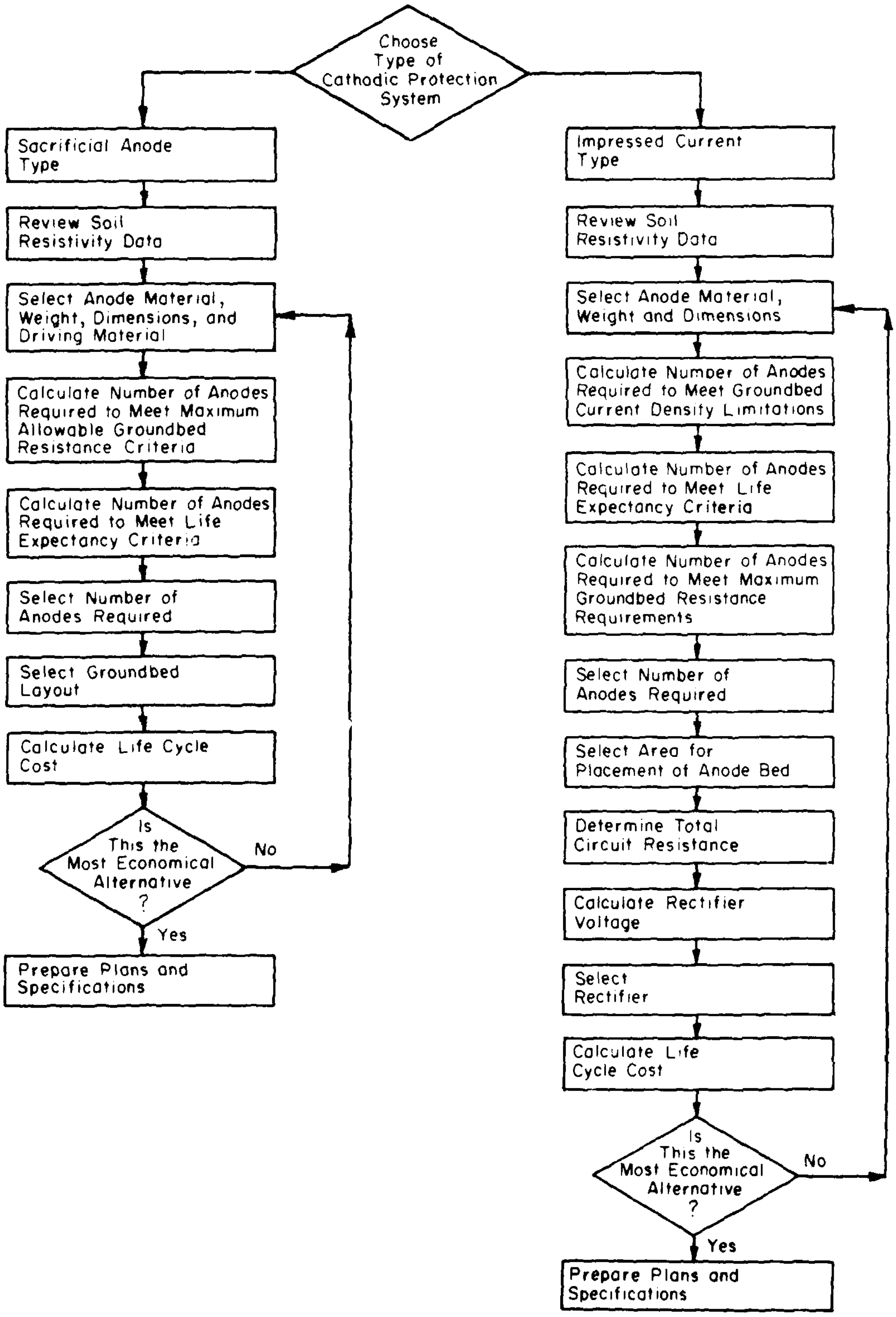

Figure 6. Design sequence for a sacrificial anode cathodic protection system.

Table 3

Typical Current Density Requirements for Cathodic Protection of Uncoated Steel

Environment	Current Density (mA/sq ft) AFM 88-9*	Current Density (mA/sq ft) Gerrard**
Neutral soil	0.4 - 1.5	0.4 - 1.5
Well aerated neutral soil	2 - 3.	2 - 3.
Wet soil	1 - 6.	2.5 - 6.
Highly acidic soil	3 - 15.	5 - 15.
Soil supporting active sulfate-reducing bacteria	6 - 42.	Up to 42.
Heated soil	3 - 25.	5 - 25.
Stationary freshwater	1 - 6.	5
Moving freshwater containing dissolved oxygen	5 - 15.	5 - 15.
Seawater	3 - 10.	5 - 25.

*Data are from Air Force Manual (AFM) 88-9, *Corrosion Control* (U.S. Air Force, August 1962), Ch 4, p 203.

**Data are from J. S. Gerrard, "Practical Applications of Cathodic Protection," *Corrosion*, Vol 2 (L. L. Shreir, Ed.) (Newnes-Butterworth, London, 1976), p 11:65.

- Protective current required. By knowing the physical dimensions of the structure to be protected, the surface area can be calculated. The product of the surface area multiplied by the current density obtained previously gives the total current required.

- Sacrificial anode (galvanic) cathodic protection system design (in accordance with requirements in TM 5-811-7).

Anodes

The anodes selected shall conform to the requirements in CEGS 16640 and SOGS 16640.

Magnesium Anodes. Magnesium anodes should be either Type I, Type II, Type III, or magnesium-manganese. These types correspond to the chemical compositions listed in Table 4. Magnesium alloy anodes can be used for soils and waters with resistivities greater than 2000 ohm-cm; they are not recommended for protecting lead or aluminum alloys. To provide protection, these anodes must create the following solution potentials:

Anode	Potential (V)
Type I	-1.55
Type II	-1.55
Type III	-1.55
Mg-Mn Alloy	-1.73

Table 4

Chemical Compositions for Magnesium Anodes (Percent by Weight)

Element	Type I	Type II	Type III	Mg-Mn Alloy
Aluminum	5.0 - 7.0	5.3 - 6.7	5.3 - 6.7	0.010 max
Zinc	2.0 - 4.0	2.5 - 3.5	2.5 - 3.5	
Manganese	0.15 min	0.15 min	0.15 min	0.50 - 1.30
Copper	0.1 max	0.05 max	0.02 max	0.02 max
Silicon	0.30 max	0.30 max	0.10 max	
Iron	0.003 max	0.003 max	0.003 max	0.03 max
Nickel	0.003 max	0.003 max	0.002 max	0.001 max
Others	0.30 max	0.30 max	0.30 max	0.05 each or 0.30 max total
Magnesium	Balance	Balance	Balance	Balance

Zinc Anodes. Zinc anodes must conform to ASTM B 418-80,[143] Type II, for fresh water and soil, and MIL-A-18001J for seawater and brackish waters; they should be used only for soil and water resistivities less than 2000 ohm-cm.

Artificial Backfill. Anodes must be factory-packaged with an artificial backfill in a water-permeable fabric sack or cardboard container. The packaging must be done on a vibrating platform to achieve dense packing, and centering shall be insured by using spacers.

Artificial backfill should be a mixture of 75 wt% hydrated gypsum, 20 wt% bentonite, and 5 wt% sodium sulfate; it must be factory-packaged around the anode in a water-permeable container which is, in turn, positioned in a water-impermeable container for shipment only. Backfill is not required for anodes used in water applications.

Criteria for Cathodic Protection

These criteria are based on the minimum voltage versus a copper/copper sulfate reference in accordance with the current version of NACE RP-01-69.[144]

Iron and Steel. A negative (cathodic) potential of at least 0.85 V. Free of IR drop caused by current flow between the anode and structures as measured between the structure and a saturated copper/copper sulfate reference electrode contacting the electrolyte. This potential is to be measured while the protective current is applied.

A polarization of 100 mV in the negative potential direction from the natural corrosion potential is required.

[143]ASTM B 418-80, "Specification for Cast and Wrought Galvanic-Zinc Anodes for Use in Saline Electrolytes," *ASTM Standards* (1983).
[144]NACE RP-01-69, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems* (NACE, 1983).

Other Metals. Criteria for protection of other commonly used metals include:

Metal	Potential vs. $Cu/CuSO_4$ (V)[145]
Lead	-0.60 (not to exceed -1.1 V)
Copper/Copper Alloys	-0.50
Aluminum Alloys	-0.95 (not to exceed -1.2 V)

SOGS Section No. 16641: Cathodic Protection System for Steel Water Tanks*

The Need for Cathodic Protection

Cathodic protection is mandatory for water storage tanks with 250,000 gal capacity or greater according to the guidelines in TM 5-811-7.

General Requirements

The cathodic protection system will be designed by an experienced, qualified contractor, who will also provide ans install all equipment, wiring, and wiring devices necessary to produce a continuous flow of direct current from electrodes in the electrolyte to the metal tank surfaces. The contractor will place the system in operation and insure complete automatic cathodic protection to prevent corrosion on the water tank's interior submerged surface. The contractor's design and installation must meet the criteria and protection outlined below in *Criteria for Protection* for a 20-year life. The purpose of the syster is to protect the metal surfaces adequately and efficiently against corrosion where the surfaces are in contact with water; this protection is in addition to the protective coating on the tank. The contract drawings will indicate the location and size of the tank.

With an impressed current system, enough anodes of the required type, size, and spacing must be installed to obtain a uniform current distribution of 3.5 mA/sq ft to all submerged surfaces in the tank when it is filled with water to the overflow level. The anodes must be suspended from the roof steel such that the hangers and supporting cables are electrically isolated from both the metal roof and the water electrolyte. The anodes must be positioned such that the roof door is midway between two adjacent anodes; they must not contact with items such as ladders, heater pipes, and stay rods.

Verification of Site Conditions. The contractor will coordinate the work with all trades required to complete the system. The general locations of the lines and structures to receive protection will be shown in the guide specifications which the contractor receives. The contractor will visit the premises to become thoroughly familiar with all details of the work and working conditions, verify existing conditions in the field, determine the exact locations of lines and structures to be protected, and advise the contracting officer of any discrepancy before beginning work. The contractor will also analyze the water and measure its resistivity and submit tnis data, along with detailed drawings of the system, for approval by the contracting officer.

[145] *British Standard Code of Practice for Cathodic Protection* (Technical Indexes Ltd., Bracknell, Berks, U.K., August 1973), p 14.

*Except where otherwise noted, all requirements shall conform to CEGS 16641 and SOGS 16641.

Services of a Corrosion Engineer. The contractor should hire a qualified corrosion engineer (licensed professional engineer or NACE-certified) to supervise and inspect the installation of the cathodic protection system.

Workmanship. All materials and equipment must be installed in accordance with the manufacturer's recommendations as approved by the contracting officer. The system must be installed and tested by an organization that has had no less than 3 years experience in this type of work or by a professional engineer registered in corrosion engineering. Installation of this system must be supervised by a registered corrosion engineer, a NACE-certified technician, or a supervisor approved by the contracting officer. The supervisor must be onsite during construction and testing.

Drawings. The contractor will develop detailed drawings of the proposed cathodic protection system including tank dimensions, anode size and number, anode material, anode-suspension details, conduit size, wire size, rectifier size and location, handhole details, wiring diagram, and any other necessary information. Shop drawings will also contain complete wiring and schematic diagrams and any other details required to demonstrate that the system has been coordinated and will function as a unit.

List of Materials and Equipment. The contractor will compile a complete list of materials and equipment to be incorporated in the work. The list will include cuts, diagrams, and other such descriptive data as may be required to define the proposed system. This list will include:

- Water resistivity and water analysis results.
- Conductors.
- Anodes.
- Coating material in areas where welding and other work is done.
- Insulated resistance wire.
- Layout of anodes in tanks, test stations, and isolation points, and grounding.
- Special details.
- Certified experience data of installing firm.
- Exothermic weld equipment and material.
- Test station.
- Welding method for electrical and steel-ring connections.
- Calculations for:
  - Total current required for system.
  - Life of the anodes.
  - Anode geometry (showing areas of coverage).

Impressed Current Anodes

Anodes can be either high-silicon cast iron or precious metal type. Whichever type is used, it must conform to CEGS 16641 and SOGS 16641 requirements.

If precious metal anodes are used, they must be in composite rod form. For example, with conductive ceramic-coated titanium rod anodes each anode rod segment should be 0.138 in. diameter by 4 ft long and should have threaded couplings at both ends. The cable-to-anode connector must be factory-assembled.

Rectifiers and Associated Equipment

Rectifiers and associated equipment must conform to CEGS 16641. Air-cooled, oil-immersed, or dust-proof rectifiers should be used only where conditions warrant or where the rectifier cannot be located indoors; stainless steel or aluminum alloy rectifier cases should be used for coastal atmospheres; selenium stacks; separate rectifier circuits for main column, stub, and riser anode strings; automatic potential controlled.

Reference Electrodes

The electrodes must be copper/copper sulfate type with a micropore diffusion window for water contact and a watertight plug for renewal of copper sulfate crystals and solution. These electrodes must be designed for a minimum 5-year life. Potentials must be measured and recorded monthly.

Automatic Cathodic Protection Control

The control system must automatically maintain the tank-to-water potential at (-) 900 mV with respect to a copper/copper sulfate reference electrode within plus or minus 0.025 V, regardless of changes in water chemistry, temperature, or water level in the tank. Provision must be made for readily changing the range and limits of the criterion. The controller shall be either housed integrally with the rectifier or in a separate lockable weatherproof cabinet. The tank-to-water potential measured and maintained by the controller must be free of IR drop error (see **SOGS Section No. 16640**).

Tank-to-Water Potential Meter

The controller should be equipped with a calibrated voltmeter that has an internal impedance exceeding 1 mega-ohm. The meter should be connected so that the tank-to-water potential can be read from the system reference cell without IR drop errors.

Installation

Special attention must be given to insure the rod anodes are located at the depth and are of the length shown in the drawings. When rod-type anodes longer than 4 ft are required, they must be assembled in a vertical position by coupling together successive lengths of rod (torque tightened to 30 ft/lb or more) while lowering the rod through the roof access hole until the anode length shown in the drawings is achieved. An "Expand-A-Rod" cable connector with the required wire length should then be attached to the top of each anode rod or rod assembly. Rod anodes should be suspended by their connecting cables, which will be wrapped once around the porcelain insulator of the anode clevis support assembly and then provided with four tight wraps of wire around the support lead before the lead is routed and spliced to the anode header cable. The splice must be waterproof and insulated with rubber PVC plastic electrical tape. Installation methods for all components must conform to the requirements in CEGS 16641 and SOGS 16641.

Criteria for Protection

The system must maintain a negative voltage of at least minus 0.85 V which is free of IR drop and is produced by current flow between the anode and tank surface as measured between the tank and a saturated copper/copper sulfate reference electrode.

To prevent disbonding of the interior coating in the tank, the potential between a copper/copper sulfate reference electrode and the tank at any point must not be more negative than minus 1.1 V when measured with the electrode located between 1/4-in. and 1/2-in. away from the steel surface (but not touching it).

Quality Control

The contractor must establish and maintain quality control for all operations to insure compliance with the contract requirements. The contractor must keep quality control records for all materials, equipment, and contruction operations including, but not limited to, proof of:

- Proper installation of all anodes.
- Proper installation of all test stations.
- Proper connection of all components.
- All tests and measurements.
- Electrical isolation of all insulating joints.
- No contact between protected system and other systems.

SOGS Section No. 16642: Cathodic Protection System (Impressed Current)*

The Need for Cathodic Protection

Cathodic protection is mandatory for underground POL storage tanks and piping, underground gas distribution piping, underground steel piping systems located within 10 ft of steel-reinforced concrete (per TM 5-811-7). The cathodic protection system should be designed and installed by an experienced, qualified contractor who specializes in corrosion mitigation techniques.

General Requirements

Verification of Site Conditions. The contractor will coordinate the work with all trades required to complete the system. The general locations of the lines and structures to receive protection will be shown in the guide specifications which the contractor receives. The contractor will visit the premises to become thoroughly familiar with all details of the work and working conditions, verify existing conditions in the field, determine the exact locations of lines and structures to be protected, and advise the contracting officer of any discrepancy before beginning work. The contractor will also

*Except where otherwise noted, all requirements shall conform to CEGS 16642 and SOGS 16642.

measure the soil resistivity and submit these data, along with detailed drawings of the system, for approval by the contracting officer.

Determining the Type and Design of Cathodic Protection System. The cathodic protection system (impressed current) should be designed based on guidance in TM 5-811-7. Figure 6 in **SOGS Section No. 16640** shows design sequence for this type cathodic protection system. Before the system is designed, the following preliminary information must be gathered:

- Physical dimensions of structure to be protected.
- Drawing of structure to be protected.
- Electrical isolation.
- Short circuits.
- Corrosion history of other structures in the area.
- Electrolyte resistivity (structure's tendency to corrode is proportional to the electrolyte resistivity, which is a measure for determining corrosivity).
- Electrolyte pH.
- Structure versus electrolyte potential (for existing structures, the potential between the structure and the electrolyte will give a direct indication of the corrosivity for determining anodic and cathodic sites and provides data for determining criteria of protection).
- Current requirement. A critical part of design calculations for cathodic protection systems on existing structures is the amount of current required per square foot (current density) to change the structure's potential to achieve design criteria. The current density required to shift the potential indicates the structure's surface condition. A well coated structure (for example, a pipeline well coated with coal-tar epoxy) will require a very low current density (about 0.05 mA/sq ft); an uncoated structure would require high current density (about 10 mA/sq ft). The average current density required for cathodic protection is 2 mA/sq ft of bare area. Table 3 in **SOGS Section 16640** gives typical current density requirement for cathodic protection of uncoated steel.
- Coating resistance. A coating's resistance decreases greatly with age and directly affects structure-to-electrolyte resistance for design calculations.
- Protective current required. By knowing the physical dimensions of the structure to be protected, the surface area can be calculated. The product of the surface area multiplied by the current density obtained previously gives the total current required.

Impressed Current Anodes and Hardware

High-silicon chromium-bearing cast iron anodes for deep-well ground beds shall be tubular, centrifugally produced, corrosion-resistant, and have a consumption rate not to exceed 1 lb/amp-yr at a current density of 1 amp/sq ft of anode. For deep-well groundbed application, these anodes must have a low-resistance, two-piece, factory-assembled

inside center cable connection to prevent premature failure. Anodes must have a mechanically secured connection wire via a precast lead connector fastened to the cable. Cable anode connections must be completely encapsulated with mastic and epoxy, with a cable guide installed at the end of the anode and a strength equal to or exceeding 1-1/2 times the maximum breaking strength of the cable. The anode/cable connection resistance shall not exceed 0.004 ohms.

Precious metal anodes shall be in composite rod form.

Rectifier and Associated Equipment

These components must conform to the requirements in CEGS 16642 and SOGS 16642.

Anode Backfill Materials

Backfill material for deep-well anodes should be prepared from calcined fluid petroleum coke. The coke granules should be essentially round and mostly carbon. Resistance should not exceed 0.10 ohm-cm at 150 psi. The basic composition should be:

Material	wt%
Moisture	0.0
Volatiles	0.7
Ash	2.23
Silicon	0.06
Iron	0.02
Sulfur	5.85
Carbon	91.77

Physical analysis should show a bulk density of 74 lb/cu ft, specific gravity of 2.0, and porosity of 40.8 percent. Particle analysis should produce the following results:

Screen Mesh Size	Percent Retained
16	0.0
28	7.4
35	86.4
80	2.3
100	3.9

Low-resistivity carbon lubricants and wetting agents should be added. The low-resistivity carbon lubricants should reduce the resistance between carbon particles, enabling faster transfer of current between particles and enhancing distribution of current over the coke bed. The wetting agents should wet the smallest particle, allowing the carbon to settle and compact as much as possible.

After the backfill is fluidized, the mixture will be pumped to the bottom of the deep-well anode bed and should not be interrupted until all backfill is in place.

Electrical Wire

Anode connecting wire for deep-well applications should consist of one continuous length of No. 8 stranded copper wire with an outer layer of 0.040- to 0.065-in.-thick, high-molecular-weight polyethylene (HMPE) and an inner layer 0.020-in. thick (minimum) ethylene CTFE or polyvinylidene fluoride.

Anode Centering Device

For deep-well applications, the anode centering device should be consumable (carbon steel) and consist of steel bonds that can bond the anodes to 1-in. outside diameter steel pipe sections that are lowered into the drilled hole.

Anode Junction Box

An anode junction box must be provided for each deep ground bed. Boxes for use in the POL areas must be explosion-proof. Junction boxes should be 10 in. by 8 in. by 4 in., be ready for wall and pole mounting, and contain Type RS Holloway shunts for each anode. Each junction box should allow for six anode terminal connections up to AWG No. 6 and 1 "positive" rectifier cable terminal connection up to American Wire Gage (AWG) No. 6 fastened securely to a fiberglass backing plate. The boxes must be the same grade coating and color as the rectifier and must be lockable. Padlocks will be furnished for locking. Stainless steel boxes must be used for locations within 1 mi of saltwater.

Ground Bed Installation

Deep-well ground beds should consist of a group of anodes centered and spaced correctly in the drilled hole and coke backfill column. The anodes will be steel-banded to lengths of 1-in.-diameter steel pipe that are coupled together and lowered into the drilled hole. The steel bands and pipe will ultimately be destroyed; however, it is critical that no tape or plastic be used to hold the anodes or cables in place. The anode string, with pipe, can be lowered into the drilled hole using the combined anode cables. The cables can be allowed to traverse a 10-in. or greater diameter pipe for support.

Drilling. The contractor must keep a stratum log while drilling each hole. In no case can plastic casing pipe be left in the hole because it would prevent the hole's use as a deep anode bed. Should the holes collapse at any time during installation, a new hole must be drilled. The actual elevation of anodes is subject to change during construction; however, lead wires must be long enough to allow placement from the bottom of the hole to the anode terminal box without splicing. Anode lead wires must be adequately marked before placement and supported at the surface in such a way that the wire insulation will not be damaged. When the hole is ready for anode installation, clear water will be pumped down the hole to flush out all debris.

The contractor must conduct a resistance survey on each hole after the drilling is complete. Resistivity is determined by lowering an anode to the bottom of the hole and applying current between the anode and the structure's grounding system. The anode used for this test must not be installed as one of the permanent anodes. The current and voltage will be recorded at each 5-ft interval from the bottom of the hole to the top and the resistivity calculated using these values. The contractor supplies the equipment needed for the tests (e.g., batteries, shunts, on-off switch).

Header Cable Splices. Cable splices are not permitted anywhere below ground. Splices above ground, if needed, must be made using high-compression crimped connectors and must be completely encapsulated by the epoxy cast kits.

PVC Vent Pipe. A 1-in. PVC vent pipe, Type 1, Class 1, must be installed from the bottom of the drilled hole to a point 8 ft above the existing grade. The pipe will be drilled with 1/8-in. holes at four 90-degree locations around its circumference. Holes should be spaced 6 in. apart along the length of the pipe to the specified depth. The top of the vent pipe should have a 180-degree elbow installed with a screen over the pipe end. Pipe at the top of the hole must slope downward toward the drilled hole.

The above-ground PVC vent pipe should be installed so that it is away from the drilled hole and is supported, for example, at a building or fence. At locations where an 8-ft-high vent cannot be supported, it can be placed close to the ground if it is protected with guard piping. The pipe from the drilled hole to the supported position is to be underground.

Placement of Backfill. Once the string of anodes is in place at the proper depth and spacing, the coke-breeze backfill is slowly pumped into the hole. As the hole and annular space around the anodes is being filled, the backfill injection pipe is raised slowly to the point where the backfill column is 1 ft below the point at which the PVC pipe vent (previously lowered to the bottom) exits the ABS casing.

*Criteria for Protection**

The system must maintain a negative (cathodic) potential of at least 0.85 V. The measurement must be free of IR drop due to current flow between the anode and structure as measured between the structure and a saturated copper/copper sulfate reference electrode contacting the electrolyte.

An alternative criterion of protection requires a polarization of 100 mV in the negative potential direction from the natural corrosion potential.

SOGS Section No. 16723: Fire Detection and Alarm System

Components	*Environment - Exposure*	*Materials Selection*
Alarm bell	Coastal - atmospheric	Copper alloy
Electronic components	Coastal - atmospheric	Electronics components must be hermetically sealed in their containers and should be assembled using noncorrosive soldering fluxes, with all halogenated cleaning solutions removed and a corrosion inhibitor incorporated into the conformal coating(s) applied to printed circuit boards.

*These criteria shall conform to CEGS 16642 and SOGS 16642 except where otherwise noted and in accordance with the current version of NACE RP-101-69.

14 MISCELLANEOUS ITEMS

Section* No. 11225: Water Desalination Plant

Component	*Environment - Exposure*	*Materials Selection*
FRP, CPVC, PB, ABS, and PE plastics	Coastal/inland	Not recommended for direct exposure to the sun or in locations of major vibration.
Coatings for exterior surfaces of diesel-engine exhaust stacks	All locations	See guidelines on high-temperature coatings in **SOGS Section 09900.** MIL-P-14105 (up to 1400°F service), MIL-P-26915, Type I, Class A (up to 750°F), or MIL-P-38336 (up to 750°F) is recommended for coastal or highly corrosive environments.

Section No. 13135: Double Corrugated Steel Arch Shelter Structures

All parts welded to the arch shall be repaired as specified in the guidance currently used by the USACE Middle East Division. All galvanizing that needs repair should be cleaned and touched up with DOD-P-21035, a cold galvanizing compound.

Section No. 15609: POL and Diesel Storage Tanks, Controls and Piping (Concrete Vault, Steel-Liner Type)

Component	*Environment - Exposure*	*Materials Selection*
POL drain tanks	Coastal/Inland-Underground	FRP storage tanks shall be double-walled horizontal type. Storage tanks shall be monitored by a leak detection system. See section on leak detection system in **SOGS Section No. 15605.**

*As explained earlier, these items are not included in the SOGS but usually are discussed using the numbers assigned here.

Component	*Environment - Exposure*	*Materials Selection*
Steel hardware with the POL drain tanks (e.g., anchor cable hooks, manways, etc.)	Coastal - Aggressive soils	Steel used for anchoring systems should be galvanized; this system should be coated with coal-tar compound, MIL-C-18480, and cathodically protected using sacrificial anodes (particularly important in areas with wet or damp, aggressive soils). Steel manways should have an external coal-tar coating, MIL-C-18480, and cathodic protection with sacrificial anodes.
Grounding pits--receptacle, stud, and pit cover	Coastal - Aggressive soils	Bronze.
Grounding pits--container used to hold the coke breeze in place around the carbon grounding rod	Coastal - Aggressive soils	Hardened copper.
POL vent pipe that extends into the cavity between the steel liner and concrete vault	Coastal	Should be capped to prevent salt-laden moisture from entering the cavity and condensing on the uncoated steel liner.
POL storage tank, interior (steel)--coating system	All locations	See painting schedule below.

POL Tank Interior (Steel) Paint Schedule

Surface Exposure	**Surface Preparation/ Pretreatment**	**Finish Type**	**1st Coat**	**2nd Coat**	**3rd Coat**
Interior POL storage	White metal blast-cleaning, SSPC-SP-5		Epoxy	MIL-C-4556 (primer) (Minimum of two coats to an average DFT of 6 to 7 mils.)	MIL-C-4556 (topcoat)

Section No. 16460: Transformers

Component	*Environment - Exposure*	*Materials Selection*
Coatings for transformer housing or casing	Coastal - atmospheric	Manufacturer's premium coating system for use in corrosive environments. Transformer cooling fin design should allow access to all parts of the fin for maintenance painting as required in the field.

15 CONCLUSION

Guidance for corrosion mitigation and materials selection has been provided for facilities constructed in the environments unique to the Middle East. This guidance is recommended for incorporation into the SOGS and the CEGS under the applicable numbers.

METRIC CONVERSIONS

1 ft = 0.305 m
1 mil = 0.025 mm
1 mi = 1.61 km
1 sq in = 6.45 cm^2
1 cu ft = 0.028 m^3
1 cu yd = 0.765 m^3
1 oz = 29.6 cm^3
1 gal = 3.785 L
1 lb = 0.454 kg
1 psig = 6.895×10^3 Pa
°F = (°C x 9/5) + 32

CITED REFERENCES

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ASTM C 150-86, "Specification for Portland Cement," *ASTM Standards* (1983).

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ASTM D 173-81, "Specification for Bitumen-Saturated Cotton Fabrics Used in Roofing and Waterproofing," *ASTM Standards* (1983).

ASTM D 226-82, "Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing," *ASTM Standards* (1983).

ASTM D 227-82, "Specification for Coal-Tar Saturated Organic Felt Used in Roofing and Waterproofing," *ASTM Standards* (1983).

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APPENDIX: A

SOGS/CEGS CROSS-REFERENCE

SOGS Section No.	Corps Specification No.	Title
02102	CE-800	Clearing and Grubbing
02210	CEGS-02210	Grading (Earthwork)
02213		Blasting
02215 (R)		Plastic Filter Fabric
02221	CEGS-02221	Excavation, Trenching, and Backfilling for Utilities Systems
02222	CE-203	Excavation, Filling, and Backfilling for Buildings
02312	CEGS-02362	Prestressed Concrete Piling
02313	CE-202.07	Piling; Concrete, Precast
02315	CEGS-02360	Steel H-Piles
02317	CEGS-02363	Cast-in-Place Concrete Piles, Steel Casing
02318 (R)	CEGS-02364	Auger-Placed Grout Piles
02320 (R)	CE-1304.02	Piling; Steel Bearing
02351 (R)	CEGS-2372	Drilled Foundation Caissons (Piers)
02353 (R)	CE-202.09	Contractor Option for Footings, Concrete, Pressure-Injected
02411 (R)	CE-02411	Steel Sheet Piling
02452		Roadway Traffic Control Signs
02455		Aircraft Tie-Down Anchors
02501	CE-02501	Storm-Drainage System
02502 (R)	CE-02502	Subdrainage System
02502	CE-02502	Subdrainage System

SOGS Section No.	Corps Specification No.	Title
02609		Bituminous Surface Course for Roads, Streets, and Paved Areas
02609		Bituminous Surface Course for Roads, Streets, and Paved Areas
02611 (R)	CE-02611	Concrete Pavement for Roads and Airfields
02611	CE-02611	Concrete Pavement for Roads and Airfields
02613	CE-807.22	Bituminous Intermediate and Surfaces Courses for Airfields, Heliports, and Tank Roads (Central-Plant Hot-Mix)
02615 (R)	CE-02615	Joint Sealing in Concrete Pavements
02617	CE-807.19	Bituminous Surface Treatment
02618	CE-820	Pavement Markings (Airfields and Roads)
02631	CEGS-02450	Concrete Sidewalks, Curbs, and Gutters and Miscellaneous Exterior Items
02666	CE-807.01	Select-Material Subbase Course
02667	CE-807.07	Graded-Crushed-Aggregate Base Course (Airfields)
02668	CEGS-02234	Subbase Course--Airfields
02671	CE-02671	Bituminous Tack Coat
02672	CE-02672	Bituminous Prime Coat
02696	CEGS-02241	Stabilized-Aggregate Base Course
02701		Aggregate Blanket
02711	CEGS-02444	Fence, Chain-Link
02712		Fence, Barbed-Wire
02730 (R)	CEGS-02530	Playing Surfaces for Outdoor Sports Facilities
02751		Landscape Irrigation System
02821 (R)	CEGS-02821	Turf

SOGS Section No.	Corps Specification No.	Title
02830		Planting of Palm Trees
02831 (R)	CE-02831	Trees, Shrubs, Ground Covers, and Vines
03230		Prestressing Reinforcement for Cast-in-Place and/or Precast Concrete
03316	CEGS-03300	Concrete (for Building Construction)
03317	CEGS-03301	Concrete for Building Construction (Minor Requirements)
03319		Concrete Placement (for Building Construction)
03412	CEGS-03410	Precast Concrete Floor and Roof Units
03413	CE-219.01	Roof Decking, Precast; Slab, Plank and Tile
03480		Precast Prestressed Concrete Units for Buildings
03522	CEGS-03510	Roof Decking, Cast-in-Place Foam-Concrete
04200	CEGS-04200	Masonry
04230	CEGS-04230	Reinforced Masonry
04401	CEGS-04401	Interior Stone
05020	CEGS-05050	Ultrasonic Inspection of Weldments
05021	CEGS-05062	Ultrasonic Inspection of Plates
05120	CEGS-05120	Structural Steel
05141	CEGS-05141	Welding, Structural
05210	CEGS-05210	Steel Joists
05301	CEGS-05311	Roof Decking, Steel
05500	CEGS-05500	Miscellaneous Metal
06100	CE-235.03	Rough Carpentry

SOGS Section No.	Corps Specification No.	Title
06200	CE-235.04	Finish Carpentry
07112	CEGS-07112	Bituminous and Elastomeric Waterproofing
07140	CEGS-07140	Metallic Oxide Waterproofing
07141	CE-222.01	Metal Roofing and Siding, Plain
07142	CE-222.02	Metal Roofing and Siding, Factory-Color-Finished
07160	CEGS-07160	Bituminous Dampproofing
07241	CEGS-07241	Insulation for Built-up Roofing
07463	CEGS-07463	Roofing and Siding, Asbestos-Cement
07510	CEGS-07510	Built-up Roofing
07530	CEGS-07530	Elastomeric Roofing (EPDM), Sheet Applied
07540	CEGS-07540	Spray Applied Elastomeric Roofing on Urethane Foam
07550		Protected Membrane Roofing System
07600	CEGS-07600	Sheet Metalwork, General
07810		Skylights
07840	CEGS-07480	Ventilators, Roof; Gravity-Type
07951	CEGS-07920	Calking and Sealants
08105	CEGS-08110	Steel Doors and Frames
08201	CEGS-08201	Wood Doors
08300	CEGS-08300	Miscellaneous Doors
08315	CEGS-13810	Doors; Fire-Insulated, Record-Vault
08353	CEGS-08353	Doors and Partitions; Accordion Type
08371	CEGS-08371	Aluminum Sliding Glass Doors
08510	CEGS-08510	Steel Windows

SOGS Section No.	Corps Specification No.	Title
08520	CEGS-08520	Aluminum Windows
08710	CEGS-08700	Hardware; Builders' (General Purpose)
08711	CE-251.02	Hardware; Builders' (for Permanent-Type Hospitals)
08712	CEGS-08701	Hardware: Prison-Locking Devices
08810	CEGS-08810	Glass and Glazing
08840	CEGS-08840	Acrylic-Plastic Glazing
09100	CE-240.01	Furring (Metal), Lathing, and Plastering
09180	CE-241	Stucco, Cement
09250	CEGS-09250	Gypsum Wallboard (Dry Wall)
09302	CE-09310	Ceramic Quarry and Terrazzo Tile
09411	CEGS-09411	Bonded Terrazzo
09422		Precast Terrazzo Elements (Not to Include Tile)
09431	CEGS-09430	Conductive Resinous Terrazo Flooring
09450	CEGS-09403	Resinous Terrazo Flooring
09500	CEGS-09510	Acoustical Treatment
09550	CEGS-09650	Wood Strip Flooring
09570	CEGS-09570	Wood Parquet Flooring
09650	CEGS-09560	Resilient Flooring
09675	CEGS-09380	Conductive Vinyl Flooring
09680		Carpeting
09703	CEGS-09431	Conductive Sparkproof Industrial Resinous Flooring
09900	CEGS-09910	Painting, General
09951	CEGS-09951	Vinyl Coated Wall Covering

SOGS Section No.	Corps Specification No.	Title
10160	CEGS-10160	Metal Toilet Partitions
10270	CEGS-10270	Raised Floor System
10600	CE-246.01	Partitions, Movable; Flush; Semiflush, and Panel Types
10801	CEGS-10800	Toilet Accessories
10910	CE-246.02	Wardrobes
10520		Extinguishers, Fire, Hand Portab!
11303		Sewage Lift Stations
11400	CE-400.02	Food-Service Equipment
11701	CE-11701	Casework, Metal and Wood (for Medical and Dental Facilities)
11710	CEGS-11710	Sterilizers and Associated Equipment
11861	CE-601.02	Incinerator, Package-Type
11866	CE-601.03	Incinerator, Medical-Waste
11000		Miscellaneous Equipment
11871	CEGS-11162	Adjustable Loading Ramp (Power)
12305	CEGS-12305	Kitchen Cabinets, Steel and Wood
12501	CE-253.01	Shades, Roll-Type; Venetian Blinds; and Draw Curtains
12502	CEGS-12502	Drapery and Draw Curtain
12503	CE-253.02	Audiovisual Blinds and Curtains
12600		Furniture, Furnishings, and Accessories (FFA)
12710	CEGS-12710	Theater Chairs
13401	CE-601	Incinerator, Rubbish and Garbage, (Natural-Draft) and (Forced-Draft)
13451	CE-232	Cold-Storage Spaces

SOGS Section No.	Corps Specification No.	Title
13602	CE-201.01	Metal Building
13750	CEGS-13750	X-Ray Shielding
14201	CE-320.01	Elevators, Electric
14202	CE-320.02	Elevators, Hydraulic
14700	CEGS-14700	Pneumatic-Tube System
15116	CEGS-15116	Welding Pressure Piping
15140	CE-602.05	Pumps; Sewage and Sludge
15141	CE-504.01	Pumps; Water, Centrifugal
15143	CE-504.02	Pumps; Water, Vertical Turbine
15178	CE-15178	Pressure Vessels for Storage of Compressed Gases
15181	CEGS-15250	Thermal Insulation for Mechanical Systems
15201	CEGS-02713	Water Lines
15240 (R)	CE-505	Elevated Steel Water Tanks
15240	CE-505	Elevated Steel Water Tanks
15241	CE-506	Steel Standpipes and Ground Storage Reservoirs
15253	CE-508	Water Softeners, Cation-Exchange (Sodium Cycle)
15254 (R)		(Electro-Dialysis) (and) (Reverse Osmosis) Water Treatment System(s)
15254		(Electro-Dialysis) (and) (Reverse Osmosis) Water Treatment System(s)
15261 (R)	CE-502	Chlorine-Feeding Machines (Fully Automatic, Semiautomatic, and Nonautomatic)

SOGS Section No.	Corps Specification No.	Title
15261	CE-502	Chlorine-Feeding Machines (Fully Automatic, Semiautomatic, and Nonautomatic)
15263 (R)	CE-503	Hypochlorite-Feeding Machines
15302	CE-15302	Sewers; Sanitary, Gravity
15303	CE-600.02	Force Mains; Sewer
15304 (R)	CE-603	Sewage-Treatment Plant Wet-Burning Process, Prefabricated
15304	CE-603	Sewage-Treatment Plant Wet-Burning Process, Prefabricated
15361		Septic Tank and Absorption Field
15401	CEGS-15400	Plumbing, General Purpose
15401	CE-300.01	Plumbing, General Purpose
15402	CE-300.02	Plumbing, Hospital
15406 (R)	CE-15406	Oxygen Piping System
15408 (R)	CE-15408	Nitrous Oxide Piping System
15409 (R)	CE-15409	Vacuum Piping System
15501	CE-700	Sprinkler Systems, Fire Protection
15605	CEGS-11140	Fueling System for Motor Vehicles, Service Station Type
15651	CEGS-15650	Central Refrigeration System (for Air-Conditioning System)
15652	CE-302.01	Refrigerating System
15653	CE-301.35	Air-Conditioning System (Unitary Type)
15687	CE-302.02	Ice Plant
15701 (R)	CE-301.02	Heating System; Steam, Oil-Fired
15702	CE-301.19	Heating System; Forced-Hot-Water, Oil-Fired

SOGS Section No.	Corps Specification No.	Title
15703	CE-301.21	Heat-Distribution Systems Outside of Buildings
15705	CE-301.23	Heating System: Forced-Hot-Water, High Temperature Water Converter and Steam Converter
15707		Chilled Water Distribution System Wet Fill and Cap
15708		Chilled Water Plant and Distribution System
15712		Hot Water Heating System Wet Fill and Cap
15713		Open Cycle Condenser Water System
15801	CE-301.08	Ventilating System, Mechanical
15802	CEGS-15805	Air-Supply and Distribution System (for Air-Conditioning System)
15812	CE-15812	Warm Air Heating Systems
15907	CE-15907	Testing and Balancing Air and Water Systems
15909	CE-300.10	Hydraulic Systems
16113	CEGS-16113	Underfloor Duct System
16115	CEGS-16115	Underfloor Raceway System (Cellular Steel Floor)
16210	CE-303.20	Generating Units, Diesel-Electric, Stationary, 10-99 kW, With Auxiliaries
16211	CE-303.21	Generating Units, Diesel-Electric, 100-300 kW, With Auxiliaries
16212	CE-303.22	Generating Units, Diesel-Electric, 300-1500 kW, With Auxiliaries
16213		Generating Units, Diesel-Electric, 1.5-6.0 MW, With Auxiliaries
16262	CE-16262	Automatic Transfer Switches

SOGS Section No.	Corps Specification No.	Title
16311	CE-303.04	Electrical Conventional Substation
16402	CE-303.01	Electrical Work, Interior
16530	CE-303.08	Protective-Lighting System
16532	CE-303.06	Electrical-Distribution and Street-Lighting System; Underground
16570	CE-16570	Watchman's Clock System
16610	CEGS-16601	Lightning Protection System
16640	CEGS-16640	Cathodic Protection System (Sacrificial Anode)
16641	CEGS-16641	Cathodic Protection System for Steel Water Tanks
16702	CE-303.10	Signaling System; Nurses' Call
16703	CE-303.11	Signaling System; Doctors' Paging
16723	CEGS-16721	Fire Detection and Alarm System
16761	CEGS-16760	Intercommunication System
16770	CE-303.13	Radio and Public-Address Systems
16781	CE-303.15	Master Television Antenna System
16852	CEGS-16855	Electric Space Heating Equipment

APPENDIX B:

LANGELIER INDEX

The Langelier saturation index, or calcium carbonate saturation index, is often used to determine whether water will be scaling or nonscaling. If the water dissolves calcium carbonate, it will not have scale-forming tendencies and therefore may be corrosive. However, if the water precipitates calcium carbonate, then scale-forming tendencies are present. Calcium carbonate is usually the main component of the scale found on heat transfer surfaces in water systems. This scale forms when $Ca(HCO_3)_2$ (calcium bicarbonate), which occurs naturally in the water supply, is converted into $CaCO_3$ (calcium carbonate) after heating. The reaction is as follows:

$$Ca(HCO_3) + \text{heat} \dashrightarrow CaCO_3 + CO_2 + H_2O$$

Although waters that form scale are less likely to cause corrosion, scale formation can greatly reduce the equipment's efficiency, while corrosive waters seriously damage equipment exposed to them.

The Langelier saturation index indicates a water's scale-forming tendencies; a positive value shows oversaturation with respect to calcium carbonate (scale-forming), and a negative value indicates undersaturation (nonscale-forming). A value of zero indicates that the water is at equilibrium (neither scale-forming nor corrosive). Table B1 shows these characteristics.

To calculate the Langelier Saturation Index, the Langelier saturation pH value (pHs) is subtracted from the water's actual pH value (i.e., L1 = pH - pHs). The pHs can be determined from the relationship between various water characteristics: temperature to which the water will be raised, total dissolved solids concentration, calcium ion concentration, and methyl orange alkalinity. The relationship between these properties is accounted for by expressing the pH at calcium carbonate saturation (pHs) as:

$$pHs = A + B - \log(Ca) - \log(\text{alkalinity})$$

Table B2 provides values for the constants and logarithms.

Although the Langelier saturation index indicates a water's scale-forming or corrosive tendencies, it is not a measure of its capacity to scale. A water with a positive saturation index and a high hardness definitely causes scale. However, a water with the same positive saturation index and a low hardness may not form any appreciable scale. The index is intended only as a guide in prescribing water conditioning for a given water system.

It should be noted that several factors can adversely influence the index's results. These include temperature differences within a system, changing operating conditions, the presence of chemical treatment in the water, and whether or not equilibrium can be attained. The index also does not consider chemical constituents in the water such as silica, sulfate, and chlorides that also greatly influence a user's corrosive or scaling tendency.

Table B1

Water Characteristics in Terms of Langelier Saturation Index

Index Value	Tendencies of Water
+ 2.0	Scale-forming, noncorrosive
+ 0.5	Scale-forming and slightly corrosive
0.0	Balanced, very little corrosion, or scale formation
- 0.5	Slightly corrosive and nonscale-forming
- 2.0	Seriously corrosive, nonscaling

Table B2

CHART I. Constant A as Function of Water Temperature

°F	°C	A	°F	°C	A	°F	°C	A
41	5	2.48	95	35	1.80	149	65	1.34
50	10	2.35	104	40	1.71	158	70	1.27
59	15	2.23	113	45	1.63	167	75	1.21
68	20	2.10	122	50	1.55	176	80	1.17
77	25	1.99	131	55	1.48	185	85	1.09
86	30	1.90	140	60	1.40	194	90	1.05

CHART II. Constant as Function of Total Dissolved Solids

Total Dissolved Solids (mg/L)	B
0	9.70
100	9.77
200	9.83
400	9.86
800	9.89
1000	9.91
1200	9.93
1400	9.95

CHART III. Logarithms of Calcium Ion and Alkalinity Concentration

Ca^{2+} or Alkalinity mg/L as $CaCO_3$ (equivalent)

mg/L	log	mg/L	log	mg/L	log	mg/L	log
10	1.00	56	1.76	158	2.20	500	2.70
14	1.15	60	1.78	178	2.25	501	2.70
16	1.20	63	1.80	200	2.30	562	2.75
18	1.25	70	1.84	224	2.35	600	2.78
20	1.30	71	1.85	251	2.40	631	2.80
22	1.35	80	1.90	282	2.45	700	2.84
25	1.40	89	1.95	300	2.48	708	2.85
28	1.45	90	1.96	316	2.50	794	2.90
30	1.48	100	2.00	355	2.55	800	2.90
32	1.50	123	2.05	398	2.60	891	2.95
40	1.60	126	2.10	400	2.60	900	2.95
50	1.70	141	2.15	447	2.65	1000	3.00

ABBREVIATIONS

ABS	acrylonitrile butadiene styrene
ACI	American Concrete Institute
AFM	Air Force Manual
AFML	Air Force Materials Laboratory
AHDGA	American Hot Dip Galvanizers Association
AI	Aggressive Index
AIME	American Institute of Mining, Metallurgical, and Petroleum Engineers
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
BT	sodium benzotriozole
CIP	clean-in-place
CEGS	Corps of Engineers Guide Specification
CPVC	chlorinated polyvinyl chloride
CTFE	chlorotrifluoroethylene
DFT	Dry film thickness
EPDM	elastomeric roofing
FFA	furniture, furnishings, and accessories
FRP	fiberglass-reinforced
HMPE	high-molecular-weight polyethylene
HQDA	Headquarters, Department of the Army
HTHW	high-temperature hot water
HVAC	heating, ventilating, and air-conditioning
INCO	International Nickel Co.
IR	infrared
IRH	International Rubber Hardness
LTHW	low-temperature hot water
MBT	sodium mercaptotriozole
MHW	mean high water
MLW	mean low water
MTHW	medium-temperature hot water
NACE	National Association of Corrosion Engineers

NAVFAC	Naval Facilities
NCEL	U.S. Naval Civil Engineering Laboratory
OCE	Office of the Chief of Engineers
O&M	operation and maintenance
PB	polybutene
PE	polyethylene
PL	Public Law
PMMA	polymethyl methacrylate
POL	petroleum oil liquid
PP	polypropylene
PSM	an arbitrary designation for a product having certain dimensions (from ASTM D 3034-856)
PVC	polyvinyl chloride
RO	reverse osmosis
SOGS	Saudi Oriented Guide Specification
SSPC	Steel Structures Painting Council
STI	Steel Tank Institute
TDS	total dissolved solids
TM	Technical Manual
USACE	U.S. Army Corps of Engineers
USA-CERL	U.S. Army Construction Engineering Research Laboratory
USAF	U.S. Air Force
UV	ultraviolet

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